OWMC

Ontario Waste Management Corporation

FINAL REPORT

Gartner Lee Associates Limited

Engineering Geologists, Hydrogeologists, Biologists, Environmental Consultants

Gartner
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Associates Limited

Consulting
Engineering
Geologists and
Hydrogeologists

Toronto-Buttonville Airport ■ Markham, Ontario ■ L3P 3J9 ■ 416-477-8400
Telex - 06-986278

PRIMARY ENVIRONMENTAL INFORMATION
PART 1
GEOLOGICAL/HYDROGEOLOGICAL INVENTORY

FOR

ONTARIO WASTE MANAGEMENT CORPORATION

BY

GARTNER LEE ASSOCIATES LIMITED

PROJECT NO. 82-1002

SEPTEMBER, 1982

Gartner Lee Associates Limited

Consulting
Engineering
Geologists and
Hydrogeologists

Toronto-Buttonville Airport ■ Markham, Ontario ■ L3P 3J9 ■ 416-477-8400
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August 24, 1982.

Mr. E. Schmidt, P.Eng.,
Ontario Waste Management Corporation,
60 Bloor Street West,
Suite 707,
Toronto, Ontario,
M4W 1A1.

Dear Mr. Schmidt:

Re: Final Report - Primary Environmental Information - Part 1 - Geological/Hydrogeological Inventory

We are pleased to submit our final report and accompanying Figure 1 for the Geological/Hydrogeological Inventory Project. The two-volume appendix describing the geology and hydrogeology for each region is being forwarded under separate cover.

We trust that this portion of the inventory of environmental considerations will be helpful in the first phase of the Facilities Development Process.

Yours very truly,

GARTNER LEE ASSOCIATES LIMITED

Grant Anderson

E.G. Anderson, P.Eng.,
Consulting Hydrogeologist,
Project Director.

DSO:jcm
Enclosure.

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1.0 INTRODUCTION:

1.1 BACKGROUND:

The Ontario Waste Management Corporation (OWMC) has implemented a "Facilities Development Process" to establish facilities for the treatment and disposal of hazardous liquid industrial waste and other hazardous waste in Ontario.

The first phase of the process involves the collection and analysis of "Primary" engineering, planning and environmental information that is basic to the evaluation of various systems options.

One component of the Primary Environmental Information is an inventory of the geological and hydrogeological conditions of southern Ontario. The importance of this type of inventory was identified early in the facilities development process, and work began in January 1982. This report summarizes the results of this inventory of *geological and hydrogeological conditions*.

The report contains a description of the objectives, scope of work, methodologies employed to derive the inventory, the study results, summary and conclusions. As well, a map which shows the individual *geological/hydrogeological regions* and a first level of interpretation of geology/hydrogeology as it relates to waste facilities development, accompanies the report.

A two-volume set of binders contains specific descriptions of the geology and hydrogeology of each of the regions. These volumes are filed in the OWMC library for future reference.

1.2 STUDY OBJECTIVES:

The fundamental objective of this study is

> *to describe the major geological/hydrogeological features of southern Ontario in order to allow a preliminary evaluation of lands for secure landfilling and other treatment systems options in relation to hazardous liquid industrial waste and other hazardous waste.*

To achieve this objective, we have divided the southern part of the province into 261 geological/hydrogeological regions. Each region has been placed into one of six zones depending on the *natural* capability of the terrain to protect ground water resources from contamination resulting from the operations of treatment facilities, transfer stations, secure landfills and other waste facilities systems. While the secure landfill option will involve a fully engineered facility, our emphasis on *natural* protection is to ensure that natural geological/hydrogeological properties of a site will serve as the second line of defense in the event of a failure.

The information that we have collected and interpreted has been evaluated in relation to the following three questions which will aid in assessing systems options:

(1) What is the *natural* capability of the geological/hydrogeological setting to contain possible hazardous liquid industrial waste and other hazardous waste?

(2) What is the *predictability* of the behaviour of possible ground water in the hydrogeological setting?

(3) In the event of an unforeseen engineering failure, what degree of lead-time does the hydrogeological setting afford to properly evaluate the failure, formulate remedial plans and implement the plans to ensure protection of public safety?

Using this approach we have stressed the inter-relationships of the geological and hydrogeological factors and their resultant significance, rather than relying on a derived list of individual or weighted criteria.

While the results of this study are provincial in scale, they can be used to carry out preliminary hydrogeological assessments of various hazardous waste systems options. Information contained in this report, -- especially the descriptions of each region contained in the two binder volumes -- will form the framework for future, more detailed investigation in preferred areas. These preferred areas will be chosen on the basis of collating data from all of the primary studies, including engineering and planning information, as well as other environmental information.

1.3 SCOPE:

The inventory is general because of its province-wide scope. All lands south of Latitude 46°N (i.e. south of North Bay) are included.

The data base -- which is comprised of published and unpublished reports, maps, and many forms of available scientific literature -- was developed by senior professionals who have combined experiences of more than 100 years in evaluating geological and hydrogeological conditions in the province.

Only broad, dominant geological/hydrogeological characteristics have been identified throughout southern Ontario because of the scale limitations imposed on the study. Local variations do exist within each of the 261 identified regions shown on Figure 1. These variations, however, will only be identified as the result of collecting more detailed site specific information in only those regions that are subsequently chosen for possible systems options.

Even at this broad regional scale, the inventory has been designed to be informative. The map and detailed regional descriptions have been prepared to identify:

(1) the dominant geological and hydrogeological characteristics within each of the 261 regions,

(2) the ability of the geological/hydrogeological environment to naturally contain potential contaminants,

(3) the regions within the provincial study area with broadly similar contaminant containment characteristics.

2.0 METHODOLOGY:

2.1 INFORMATION MANAGEMENT SYSTEM:

The first task of the study was to collect, annotate and file relevant information required to identify and subsequently evaluate the various geological/hydrogeological regions of southern Ontario. Reports, maps and scientific papers were gathered and filed for ready reference.

This data base consisted of:

- water well logs and ground water reports,
- drift thickness maps,
- Quaternary Geology reports and maps,
- bedrock geology reports and maps,
- aggregate study reports and maps,
- sub-surface information from geotechnical investigations,
- physiographic maps,
- engineering terrain maps and reports,
- previous waste management studies,
- gas well records
- scientific papers and university theses.

A bibliography of selected references has been prepared for each region and is on file.

Using this information as a base, senior professional staff delineated 261 separate regions within southern Ontario as shown on Figure 1. Each of these regions was researched using the accumulated data base, and appropriate references were filed according to region. Data Resource Sheets were used to record the dominant geological features and dominant hydrogeological features for each region. These sheets are contained in the two volume binder set which is filed in the OWMC library. All pertinent back-up information is kept on permanent file.

Each region was plotted on a common base map of southern Ontario (Figure 1) and this map forms a permanent record of the locations of the 261 regions.

2.2 EVALUATION TASKS:

The first task undertaken by the senior investigators was to evaluate the broad physiographic characteristics of the province. Chapman and Putnam "Physiography of Southern Ontario" (1966, 1972) was used as the basis of this *physiographic evaluation*. Their maps -- at a scale of 1:250,000 -- provided an ideal base for identifying and evaluating the gross regions of the province.

Once the study team had identified these physiographic regions, they then grouped or subdivided them further on the basis of geological and hydrogeological characteristics as they relate to waste facilities development. Ultimately, 261 such regions were identified.

The next stage involved the utilization of the extensive data base to evaluate both the geological and hydrogeological characteristics of each region.

The *geological evaluation* consisted of a thorough review of existing geological literature by senior professionals to determine the extent and complexity of both the surficial landforms and suspected stratigraphy.

To accomplish this evaluation we analyzed detailed Quaternary Geology reports and maps, aggregate assessment reports, topographic maps, bedrock geology reports, published geological sections showing stratigraphic relationships and other available data sources. The qualified judgment of experienced senior staff was melded into the program at this stage.

The result of this geological review was a summary description of the geologically significant factors for each of the 261 regions as they relate to waste facilities development. These reviews are recorded on the Data Resource Sheets for each region.

After these geological evaluations were recorded, the *hydrogeological conditions* of each region were studied. To accomplish this task the senior investigators reviewed the hydrogeological characteristics of the stratigraphic setting identified by the geologists. Ministry of the Environment water supply reports and basin studies (where available), selected water well data, regional, county and site-specific hydrogeological waste management studies and preliminary assessments of permeabilities, attenuation properties and ground water flow systems were evaluated.

The final stage of this evaluation program was the *collation* of these data. The information for each region was analyzed in relation to the ability of the environment to naturally contain potential contaminants. In this collation, a first level of interpretation of the geological/hydrogeological data base was completed and is expressed in colour on Figure 1. Here, lands of similar geological/hydrogeological characteristics are grouped into one of six zones and are portrayed in six different colours.

All of the information used to evaluate these 261 regions of southern Ontario are retained in our information management system. Information for any region within the provincial study area can be retrieved, and forms the basis for further, more intensive studies at a later stage in the process.

3.0 STUDY RESULTS:

3.1 GEOLOGICAL/HYDROGEOLOGICAL REGIONS:

We have identified 261 geological/hydrogeological regions within southern Ontario. The locations of these regions are shown on Figure 1.

Each region is variable in size and shape since it is identified on the basis of geological and hydrogeological characteristics that are common within each region. The boundaries of these regions are a function of the natural physical environment and, as such, they transcend man-made jurisdictional boundaries.

The two-volume appendix (retained at the OWMC central library) contains the descriptions of each of these regions.

At this stage of the investigation, the descriptions of these regions are restricted to the geological and hydrogeological characteristics. We have included three Data Resource Sheets on Figures 2, 3 and 4 as examples of the type of information included under the 'Geology' and 'Hydrogeology' headings. Here is presented a summary description of both the geological features and stratigraphic relationships under the heading 'Geology'. The 'Hydrogeology' section describes the regional ground water conditions common to each region. The three regional

Region 223

GEOLOGY:

Region 223 is a portion of the Ottawa River valley. In general there are variable but often thick deposits of marine clay throughout the region. Locally there are bedrock outcrops, areas of till plain, and surficial sand deposits.

Region 223 is located along the South Nation River in South Plantagenet Township. It was delineated on the basis of well plots showing at least 40 m of clay. There are only eight wells recorded in the region. The general geological setting is similar to that of Region 26 except that the surface clays have been reworked as alluvium (Gadd 1975, Gwyn and Loshe 1973). Landslides are present in the general area, although not specifically in Region 223.

HYDROGEOLOGY:

Region 223 coincides with a portion of the South Nation River valley and is dissected by the river. Regionally the river is a ground water discharge zone, and thus flow will be towards the river at least in the overburden. Topographically the region is relatively flat and is poorly drained. There is one significant wet area within the region.

Based on limited sub-surface information, the marine clay appears to be uniformly around 40 m thick over the bedrock. Surficially, these clays may be re-worked, and could contain lenses or seams of sand. The marine clay is slowly permeable in the order of 10^{-9} to 10^{-10} m/s. Ground water flow is very slow, in the neighbourhood of .01 m/a. Attenuation potential of the clay is good.

Region 74

GEOLOGY:

Region 74 is a small area of clay plain southeast of Port Ryerse along the Lake Erie shoreline (Chapman and Putnam 1972). Barnett (1978) confirms the presence of the clay area at surface and presents shoreline bluff sections that indicate the clay ranges from 7 to 10 m thick and is underlain by "glaciolacustrine sand, silt (varved)." These sandy materials are the distal facies of a buried delta known to exist in the area (Barnett 1978). Barnett also indicates a total drift thickness of 50 m or more. Hewitt and Liberty (1972) note the presence of Dundee Formation limestone in Region 74.

HYDROGEOLOGY:

Ground water movement in Region 74 is southerly to discharge into Lake Erie. Thus flow gradients are probably lateral to slightly downward over most of the region, except adjacent to Lake Erie where upward gradients are anticipated.

The surficial clays are slowly permeable, probably around 10^{-9} to 10^{-10} m/s. Thus pore water velocities are likely only about 0.01 m/a. However if fractured, the fracture permeability could be 10^{-5} to 10^{-7} m/s. Some dessication of the upper horizon of the clay is probable, with resulting fractures.

Beneath the lacustrine clay, there is a bed of sand and silt. This bed is water-bearing and could provide a source of water to local wells. The permeability of this unit is variable due to interbedding of the sands and silts, but will likely range from 10^{-4} to 10^{-7} m/s. Ground water flow patterns will be complex with both lateral and vertical components, and velocity will range from less than 1 m/a to more than 10 m/a, depending on the soil type.

The limestone bedrock also forms an aquifer. Ground water flow is estimated at 10 to 30 m/a average in the rock.

Region 105

GEOLOGY:

"East of the Holland Marsh the Algonquin Lake plain consists of level plains based on deep deposits of sand and silt." (Chapman and Putnam 1966, p.306). The local geology (Gwyn and White 1973) suggests that outwash and the Newmarket sand to silty sand till underlies the lacustrine sand and silt. Chapman and Putnam note (ibid) that the area is poorly drained. Near the edge of the region, gravel is present beneath the fine sands. Silt and very fine sand occurs to depths of at least 7 m in the Holland Landing area.

HYDROGEOLOGY:

Region 105 forms part of the lowland complex associated with the Holland Marsh. As such the region is generally a ground water discharge zone for water recharged into the system from the surrounding till highs.

The soil consists of a variable thickness of lacustrine sand underlain by generally lacustrine clay and silt, though some till may occur, particularly in the south. The sand is fine in texture with local interbeds of silt. The permeability is around 10^{-5} m/s, and ground water flow will be 1 to 10 m/a, depending on the hydraulic gradients. The sands can form an unconfined aquifer with a locally high water table.

The clayey silt to silty clay is slowly permeable, (10^{-7} to 10^{-9} m/s). Ground water movement is likely <1 m/a through the soil. The clay tends to be wet (moisture contents are often wetter than the liquid limit) and is moderately sensitive.

Data Resource Sheets shown on Figures 2, 3 and 4 represent examples of a variety of geological and hydrogeological conditions across the province.

By referring to Figure 1, the reader can choose any area in southern Ontario and then obtain a reconnaissance assessment of its geological and hydrogeological characteristics by reading the corresponding descriptions on the Data Resource Sheets.

3.2 FIRST LEVEL INTERPRETATION OF REGIONAL CHARACTERISTICS:

In order to collate and form a first level interpretation of the large amount of information gathered during this provincial study, we have divided the 261 regions into six zones, as shown on Figure 1. These zones were developed by grouping together those regions with similar geological and hydrogeological characteristics, as they relate to waste facilities development for hazardous liquid industrial waste and other hazardous waste.

ZONE #1: In this zone we have grouped together all those regions that generally consist of silt and clay soils. These soils normally have lateral and vertical textural uniformity which is essentially predictable. Characteristically they have good attenuation properties, they have very low permeabilities that permit only extremely slow movement of ground water, and they will naturally restrict potential contaminant movement.

There may be local areas within these regions that exhibit variability, but information collected to date suggests that any such anomalies would be rare.

Thus, the regions included in Zone #1 exhibit good natural conditions for the siting of waste facilities.

ZONE #2: Subsurface conditions within the regions grouped under this zone consist of a variety of geological materials and/or a variability within a single geological unit. This results in variations in geological and hydrogeological characteristics within each region. These could consist, as an example, of glacial till soils overlying at variable depths,deposits of ice-contact sands and gravels, as typified in Region 248; or a region such as 24, where there are a variety of landforms ranging from marine silts and clays, to till plains to occurrences of bedrock outcrops.

There may be, however, local areas containing deposits of silts and clays that exhibit textural uniformity. These areas can only be delineated by carrying out more detailed studies. If discovered, these local areas will provide natural containment of potential contaminants. The detailed studies would have to delineate preferred silt and clay soils to avoid contaminant migration concerns associated with buried and surficial sand and gravel deposits.

An alternative to avoiding areas of potentially rapid movement of contaminants within these regions would be the total reliability of an engineered containment design.

ZONE #3: This zone contains regions that generally have fine sand and silt soils. Variations in geologic and hydrogeologic characteristics exist. Attenuation potential is moderate to low, and contaminants may move at moderate rates through these soils.

A region typical of this zone is Region 198, where the tills are sandy silt to silty sand in texture and may allow subsurface migration.

At this stage of investigation, we would expect that any facility developed within this zone may have to rely totally on an engineered system for containment of contaminants.

ZONE #4: Subsurface conditions here are generally permeable sands and gravels that either extend to depth in regional ground water recharge areas, or form predominant surface deposits resulting in unconfined aquifers.

Region 104, which is the Oak Ridges Moraine, is a good example of a major ground water recharge area that has deep and complex permeable soils interlayered with clays and tills. Precipitation entering this geologic feature recharges regional aquifers. Region 70 is the Haldimand-

Norfolk sand plain that constitutes an extensive shallow unconfined aquifer of surficial sands.

Although soil conditions in this zone are often predictable, attenuation potential is low, and contaminant movement can be potentially rapid through these deposits in their natural state.

Total reliance on an engineered system to control potential contaminant movement will be required in regions mapped within this zone.

ZONE #5: There are a few regions within southern Ontario that have been mapped as consisting almost totally of organic terrain. The Holland Marsh, Region 102, is an example of such an area.

In this zone, subsurface conditions generally consist of organic materials deposited in topographically low areas. Although the attenuation potential of organics is high, the threat of flooding, high ground water tables, moderate ground water movement and the highly compressible nature of the organics and underlying soils, would necessitate the total reliance on sophisticated and complex engineering systems to contain contaminants.

ZONE #6: Subsurface conditions in this zone are generally characterized by moderately permeable soils overlying bedrock. Soil texture and depth is variable and usually allows rapid movement of ground water to the underlying bedrock. Region 127 which is Prince Edward County is a good example of such a condition.

Ground water flow in the upper bedrock is usually associated with open fractures and bedding planes which commonly have variable hydrogeological characteristics. These factors usually necessitate total reliance on an engineered system for contaminant containment at any proposed facility.

4.0 SUMMARY AND CONCLUSIONS:

This primary inventory of geological and hydrogeological conditions within southern Ontario has resulted in the identification of 261 regions, as shown on Figure 1.

A two-volume set of binders filed at the library of OWMC contains detailed descriptions of the geological and hydrogeological conditions within each of these regions. The selection of these regions was based on an office study of extensive available literature and an evaluation by senior experienced professionals. The regions were chosen on the basis of geological and hydrogeological characteristics as they relate to the treatment and disposal of hazardous liquid industrial waste and other hazardous waste only.

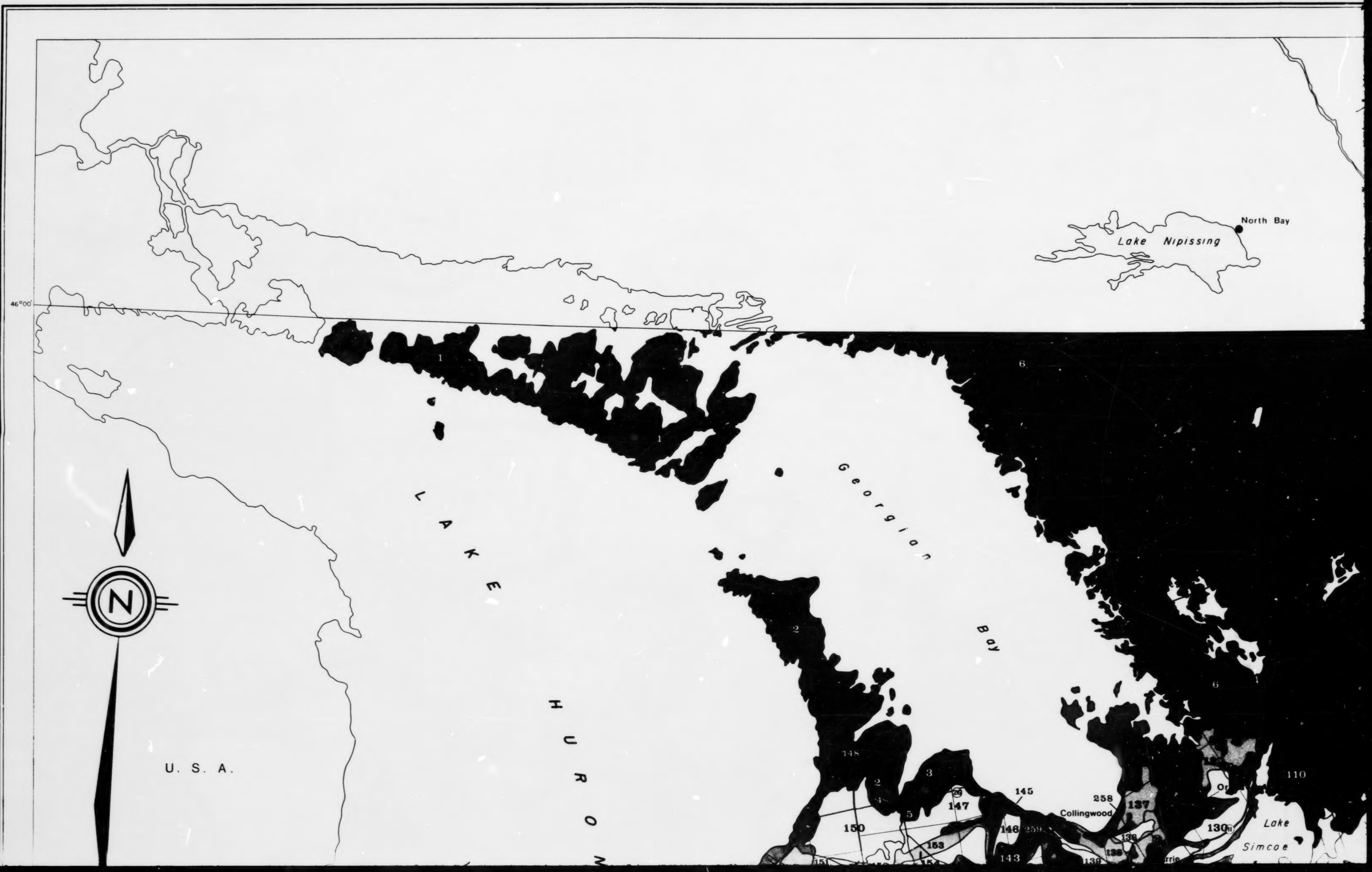
A first level interpretation of the geological/hydrogeological data base was then completed. Regions having similar characteristics were grouped together and portrayed on Figure 1 as six different zones.

Two of these six zones appear to have geological and hydrogeological characteristics that will *naturally* restrict contaminants. These are Zone #1 and Zone #2.

Zone #1 appears to have the most predictable and uniform subsurface conditions for naturally restricting contaminant movement. It is expected that adequate contiguous areas could likely be found and proven to be suitable within any of the regions identified in Zone #1.

Zone #2 identifies those regions where variability exists, but this terrain may *locally* provide containment of potential contaminants. It will be more difficult and more costly to isolate adequate contiguous areas within these regions compared with the regions in Zone #1. Within some of these regions, suitable subsurface conditions may indeed not be available.

Zones #3, #4, #5, and #6 have the least potential for the discovery of naturally suitable lands for waste facilities development. Within the regions located in these zones it is likely that total reliance on engineered systems to contain contaminants will be required.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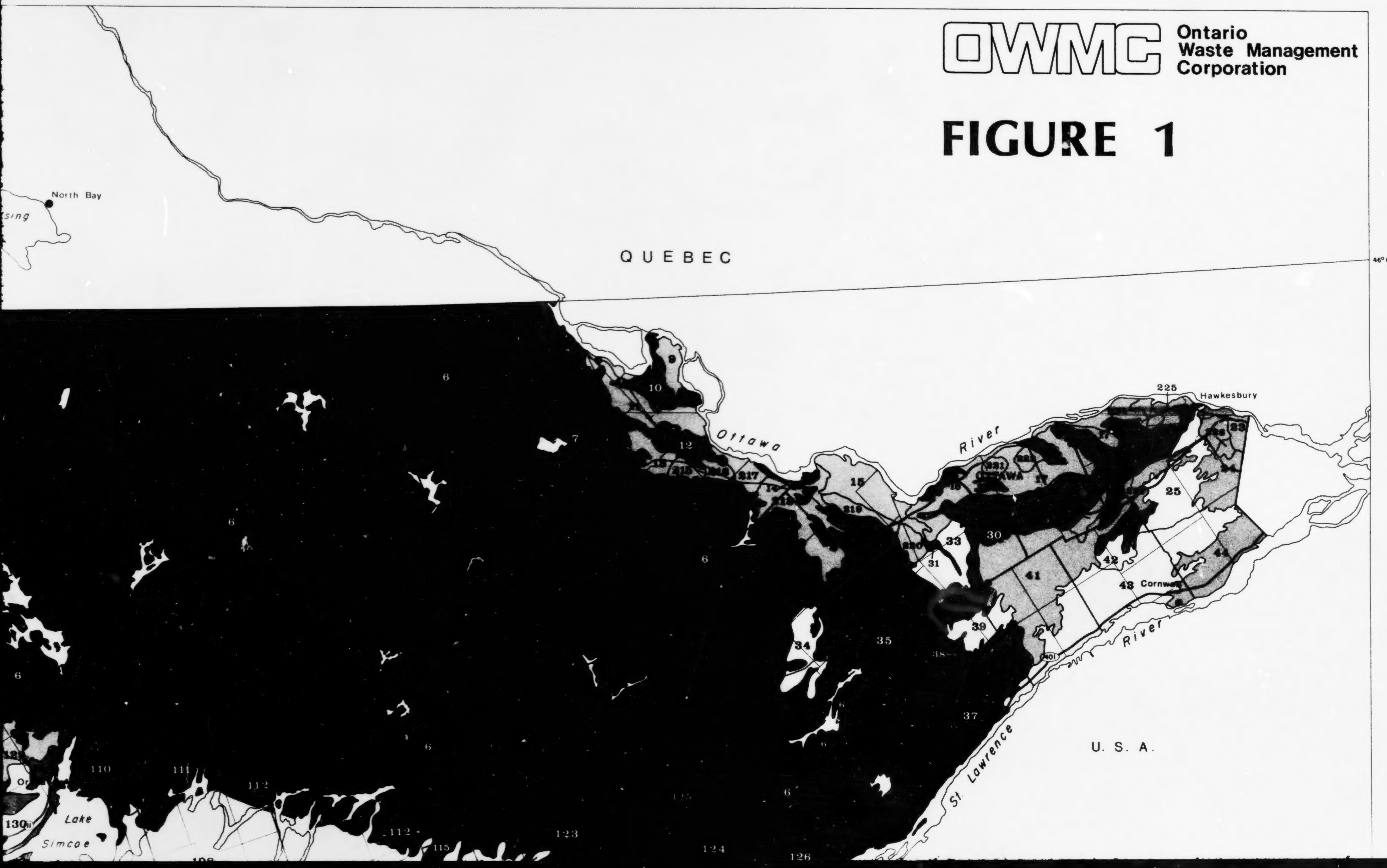
OWMC Ontario Waste Management Corporation

FIGURE 1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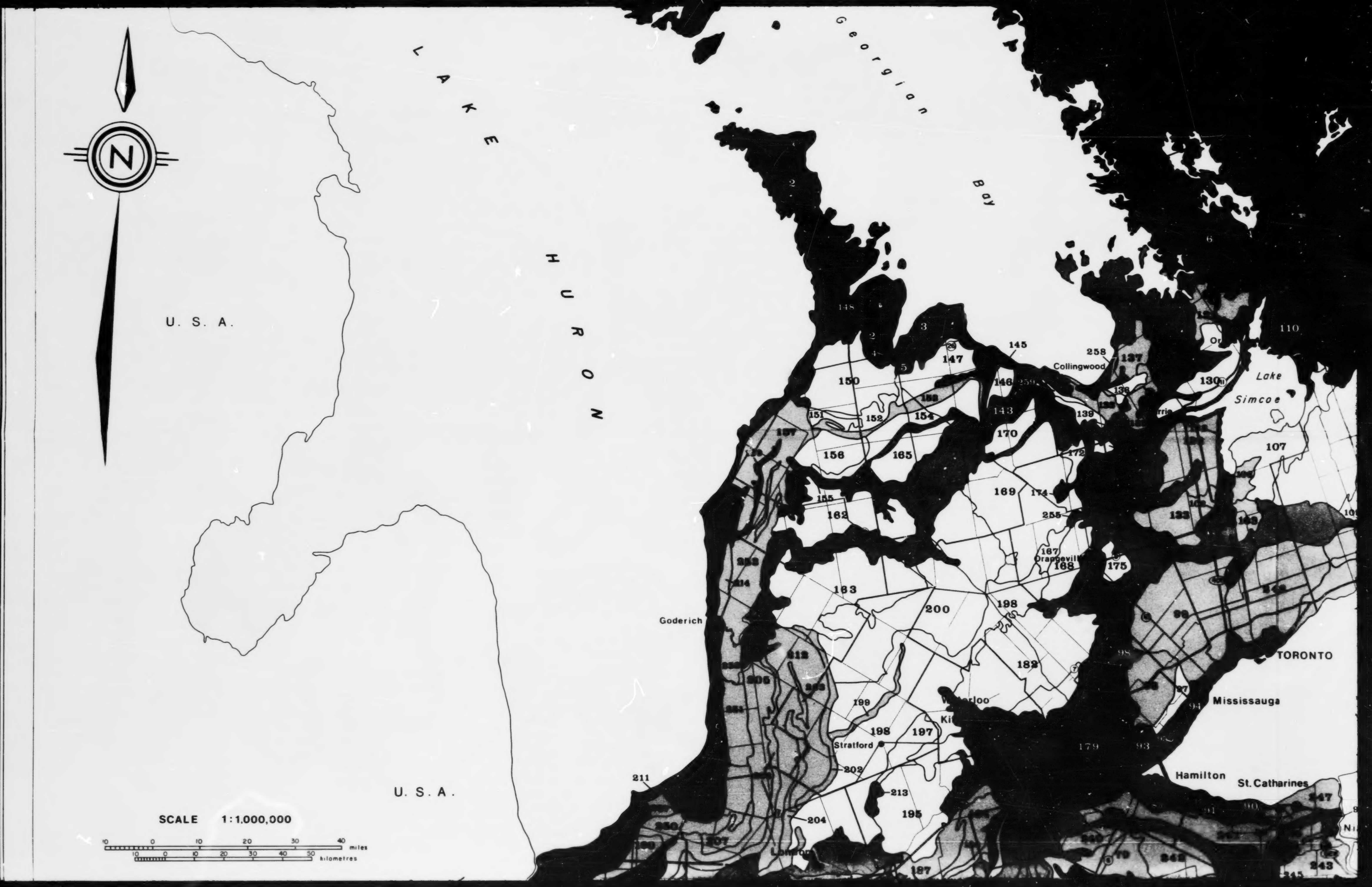
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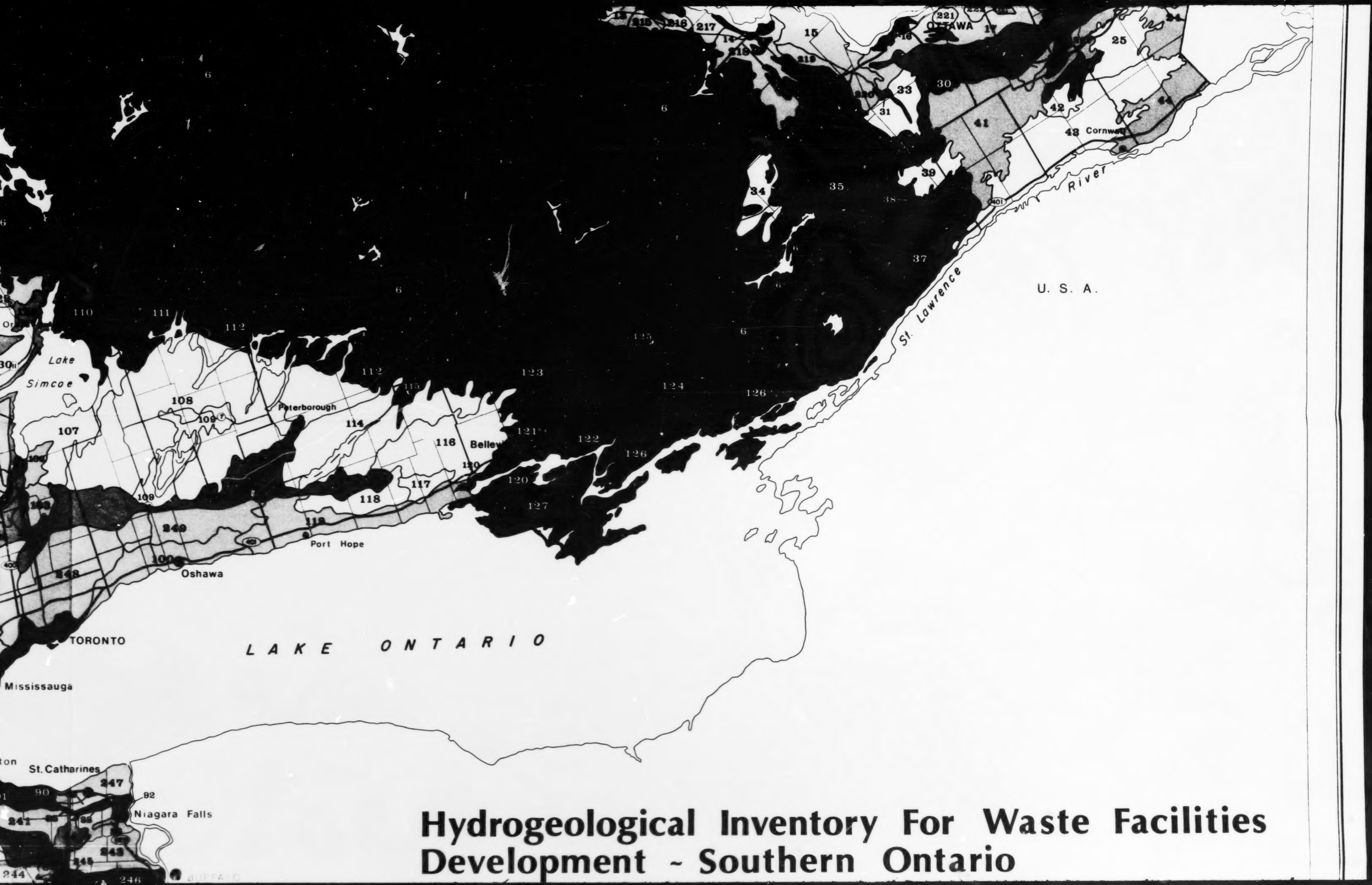
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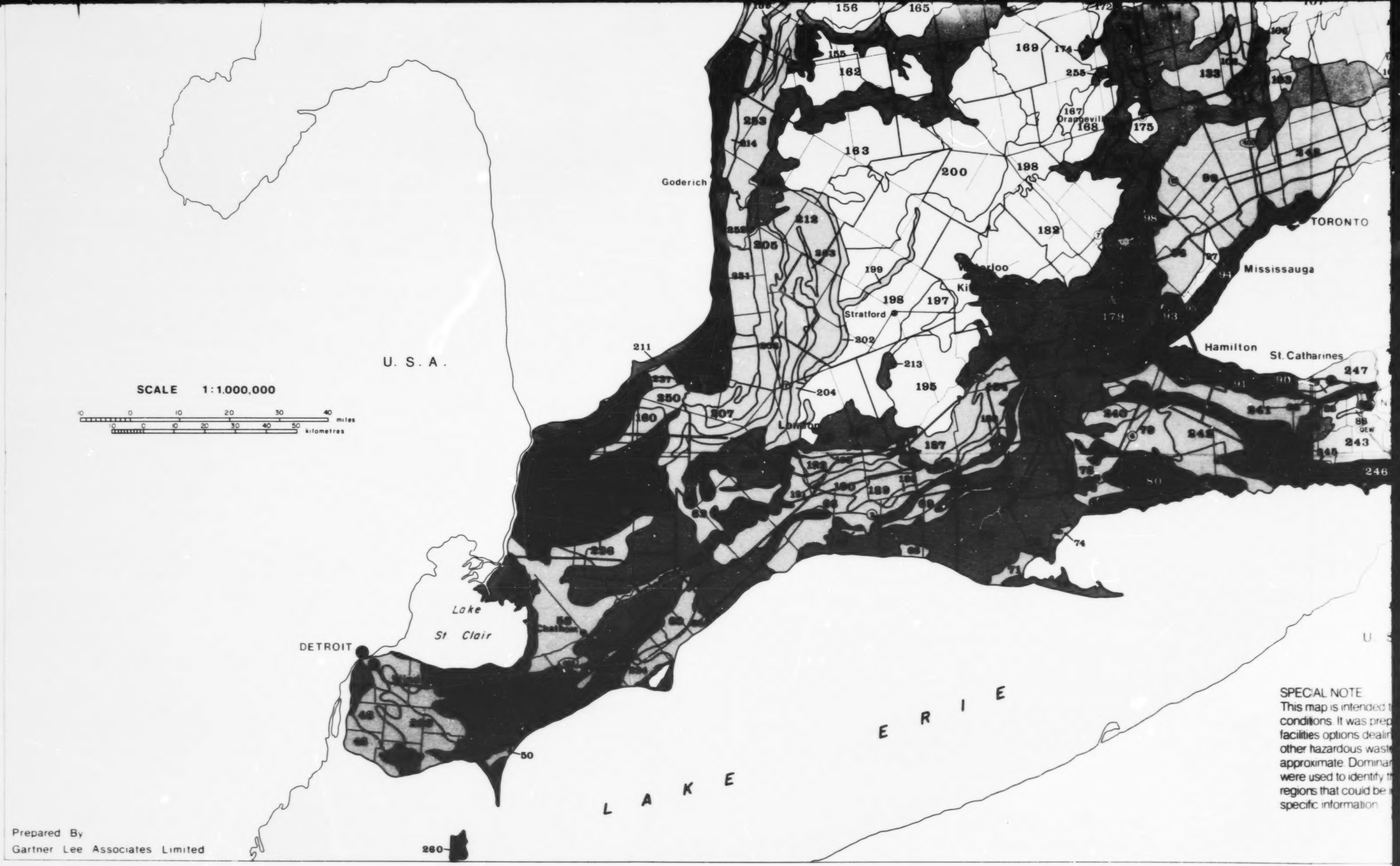
Hydrogeological Inventory For Waste Facilities Development - Southern Ontario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SPECIAL NOTE
This map is intended t
conditions. It was prep
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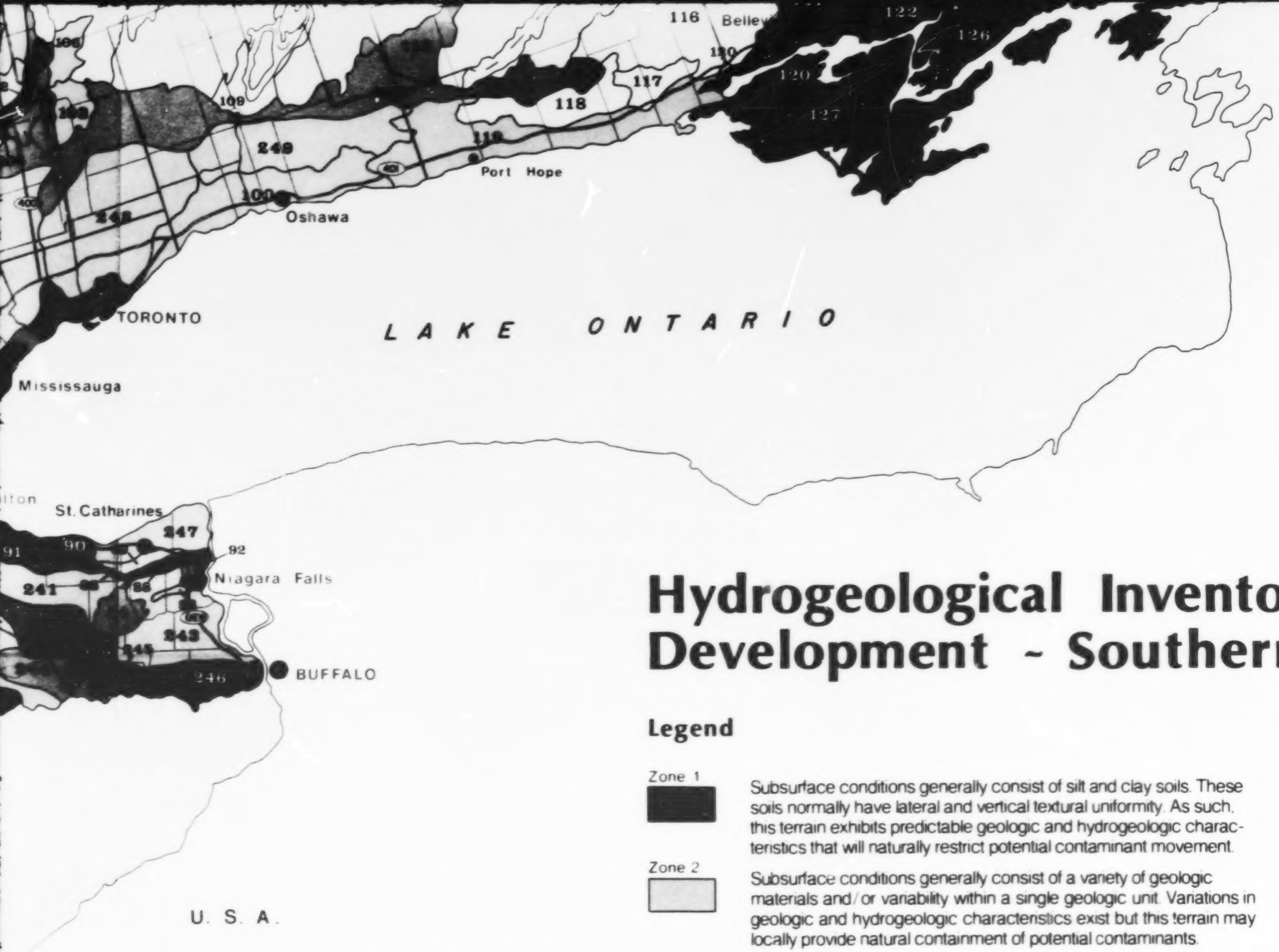
other hazardous waste
approximate. Dominan
were used to identify th
regions that could be
specific information.

Prepared By
Gartner Lee Associates Limited



Hydrogeological Inventory For Waste Facilities Development - Southern Ontario

Legend

Zone		
Zone 1	■	Subsurface conditions generally consist of silt and clay soils. These soils normally have lateral and vertical textural uniformity. As such, this terrain exhibits predictable geologic and hydrogeologic characteristics that will naturally restrict potential contaminant movement.
Zone 2	░	Subsurface conditions generally consist of a variety of geologic materials and/or variability within a single geologic unit. Variations in geologic and hydrogeologic characteristics exist but this terrain may locally provide natural containment of potential contaminants.
Zone 3	□	Subsurface conditions generally consist of fine sand and silt soils. Variations in geologic and hydrogeologic characteristics exist. These soils may allow moderate movement of potential contaminants and may not provide containment in their natural state.
Zone 4	▓	Subsurface conditions generally consist of predominantly sands, and gravels possibly underlain by or intermixed with other materials. The sands and gravels allow rapid movement of potential contaminants and do not provide containment in their natural state.
Zone 5	■	Subsurface conditions generally consist of saturated organic materials. These conditions necessitate the reliance on complex engineered systems to provide containment of potential contaminants.
Zone 6	■	Subsurface conditions are generally controlled by bedrock. Overburden will normally allow rapid movement of ground water to the rock. Flow in the upper rock mass is commonly associated with open fractures. These conditions usually do not provide natural containment of potential contaminants.

260 Hydrogeological Region

SPECIAL NOTE

This map is intended to be an inventory of regional hydrogeological conditions. It was prepared to assist, at the planning stage, in siting facilities options dealing with hazardous liquid industrial waste and other hazardous waste only. The boundaries of the regions are approximate. Dominant geologic and hydrogeologic characteristics were used to identify the regions. Local variations do exist within the regions that could be identified on the basis of more detailed site specific information.

Number/
Numéro

2

OWMC

Ontario Waste Management Corporation

FINAL REPORT

PRIMARY ENVIRONMENTAL INFORMATION
PART 2
SURFACE WATER INVENTORY

Gartner Lee Associates Limited

Engineering Geologists, Hydrogeologists, Biologists, Environmental Consultants

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PRIMARY ENVIRONMENTAL INFORMATION
PART 2
SURFACE WATER INVENTORY

FOR

FACILITIES DEVELOPMENT PROCESS
ONTARIO WASTE MANAGEMENT CORPORATION

PROJECT NO. 82-1006

SEPTEMBER, 1982

Gartner Lee Associates Limited

Consulting
Engineering
Geologists and
Hydrogeologists

Toronto-Buttonville Airport ▪ Markham, Ontario ▪ L3P 3J9 ▪ 416-477-8400
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September 2, 1982.

Mr. E.H. Schmidt, P.Eng.,
Project Director,
Ontario Waste Management Corporation,
60 Bloor Street West,
Suite 707,
Toronto, Ontario,
M4W 1A1.

Dear Mr. Schmidt:

Re: Final Report - Primary Environmental Information
Part 2 - Surface Water Inventory (GLAL 82-1006)

We are forwarding our Final Report on the surface water inventory as prepared jointly by Gartner Lee Associates Limited and Gore & Storrie Limited. The Gore & Storrie Limited technical submission is included as Appendix I and has been summarized in Section 4.2 of the text.

We trust that the information presented is helpful in identifying logical facilities development options.

Once again, we are pleased to have been of service.

Yours very truly,

GARTNER LEE ASSOCIATES LIMITED

Grant Anderson

E.G. Anderson, P.Eng.,
Project Director.

DSO:jcm

TABLE OF CONTENTS:

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1.0 INTRODUCTION:

1.1 BACKGROUND:

The Ontario Waste Management Corporation (OWMC) is currently involved in the first phase of study in its Facilities Development Process. This phase of the process deals with the *inventory* of basic engineering, environmental and planning information upon which development of a hazardous liquid industrial waste and other hazardous waste treatment facility is largely dependent.

The report describes one component of the primary environmental information being collected -- an inventory of fundamental surface water data which is basic to understanding the significance of liquid effluent discharges to the *aquatic* environment. The report complements a geological/hydrogeological inventory, basic to understanding the significance of disposal of solid residues in the *terrestrial* environment; and a discussion of climatological considerations, basic to an understanding of behaviour of emissions to the *atmospheric* environment.

Normal practice in Ontario is to treat the bulk of municipal and industrial wastes by a combination of physical, chemical and biological treatment processes. The resultant treated wastewater is often discharged to provincial lakes or rivers with the bulk of waste constituents removed. It is likely that the ultimate treatment system developed by OWMC will include a liquid treatment facility discharging effluent directly or indirectly to the *aquatic* environment.

1.2 STUDY OBJECTIVE:

This report is intended to make available to the study team, general information basic to the assessment of the impacts of a liquid effluent on provincial surface waters. This information relates to:

(i) the important uses of surface waters;

(ii) the *natural* capability of the receiving environment to disperse/dilute/assimilate a liquid effluent; and

(iii) the predictability of the behaviour of the emission in the receiving environment.

With this framework in mind, the main objective of this study is:

> *to document basic surface water considerations which relate to the natural capability of a river or lake to receive treated waste water while avoiding interference with existing uses.*

1.3 SCOPE:

This study is general in scope and applies to southern Ontario -- i.e. south of North Bay. Data have been brought together to provide a picture of significant surface water considerations across the province and are not intended to be accurate at the local level. Local information will be presented in later stages of the Facilities Development Process once feasible facilities options have been identified and potential target areas have been located. To date, only published data have been utilized. No field work was conducted in the course of the primary surface water inventory.

2.0 STUDY APPROACH:

For the inventory focus of this study, most effort was directed towards gathering and reviewing published information on major surface water uses, streamflow and Great Lakes coastal data.

2.1 SURFACE WATER USES:

Basic surface water uses regarded as most vulnerable to interference from waste treatment liquid effluents are:

- public beaches
- municipal and industrial water intakes
- municipal/industrial effluent discharges to surface waters
- near-shore spawning areas in the Great Lakes
- important inland spawning areas

The locations of public beaches were drawn mainly from an extensive tourism and outdoor recreation study conducted by the Ministry of Natural Resources (MNR), and published in 1975. In addition, locations of provincial parks and conservation areas with designated swimming beaches and facilities were obtained from an MNR listing of provincial parks (unpublished) and MNR Map 5827 entitled "Guide to Conservation Areas". Only those municipal beaches which were listed as supervised were included.

The locations of major municipal and industrial water intakes and outfalls in southern Ontario were obtained from the files of the Great Lakes Assessment Unit, Water Resources Branch, Ontario Ministry of the Environment (MOE) as well as from the Pollution Control Branch of the same Ministry. Detailed information obtained on the quantitative and qualitative characteristics of these surface water intakes and outfalls is available in the files of the study team.

Major spawning areas of important sports fish were located from published information and through telephone interviews with MNR District Biologists and Fisheries Assessment Unit Biologists. The publications reviewed and experts contacted are too numerous to list here but are cited in the references. Of greatest help were the interviews with MNR staff; a 1968 Report on former Lake Trout spawning grounds in Lake Huron by the Department of Lands & Forests; and MNR Map SF-1 entitled 'Trout and Salmon Migratory Routes in Southern Ontario Streams' (1973). Out study concentrated on salmonid species, walleye and whitefish and was restricted to major spawning areas in the Great Lakes and to important spawning streams. It is acknowledged that other species such as yellow perch, bass and smelt are of importance and that other significant inland fisheries exist; however, the species and locations considered were judged as most vulnerable to possible interference from a liquid effluent. Also, it should be noted that existing and former spawning grounds were included in our review in support of possible rehabilitation efforts for some of the sports species.

2.2 STREAMFLOW AND DISPERSION IN GREAT LAKES COASTAL REGION:

There exists in southern Ontario an intensive network of streamflow gauging stations operated as part of a national network by Environment Canada. Additional stations are operated by MOE, mostly on a seasonal basis. The streamflow information arising from this monitoring network is usually available in daily form although some stations record hourly readings. Data from each station are reported annually and the following reports served as the basis of this streamflow inventory:

(i) Historical Streamflow Summary, Ontario, to 1979; published by the Water Survey of Canada;

(ii) Low-Flow Characteristics of Streams in Southeastern Ontario, the Toronto-Central Region, Southwestern Ontario and Northeastern Ontario; a series of four regional maps published by MOE; and

(iii) Selected Streamflow Data for Ontario, Water Resources Bulletin, published annually by MOE.

Liquid waste treatment plants generally discharge in a continuous manner at a relatively constant discharge rate. At any particular time and flow rate in the receiving stream, this discharge will normally be adequately diluted by the stream. However when streamflow is low, dilution of the discharges will decrease, and thus may contribute to environmental stress on the stream below the discharge point. As a result, representative low streamflow figures for the monitored reaches of the major streams in the study area were selected rather than for example, the average flow figures. Representative low flows are expressed in various ways depending on the period of record available. Our review focussed on the minimum daily discharge, the 99% duration flow, the $_7Q_{10}$ and the lowest observed flow.

Once low-flow figures were extracted from federal and provincial records, they were tabulated, categorized and mapped for the major streams in southern Ontario.

Dispersion considerations in the Great Lakes coastal region were addressed by Gore & Storrie Limited. Again published material was reviewed. This review and the direct experience of the scientist resulted in a synopsis of the use of the coastal region of the Great Lakes for dispersion of effluents.

3.0 SURFACE WATER USES:

3.1 MAJOR PUBLIC BEACHES (FIGURE 1):

The locations of public beaches are provided in Figure 1 entitled "Surface Water Uses".

A total of 176 supervised beaches are recorded for southern Ontario. This total is composed of beaches in one Federal Park, 23 Provincial Parks and 98 Conservation Areas where swimming is advertized. Supervised municipal beaches constitute the remaining 54 locations.

It should not be forgotten that many additional beaches are situated along sections of the shorelines of the Great Lakes and many inland lakes. Since they are not supervised, they were not included in this preliminary inventory. In later stages of the facilities development process, such public beaches will be located and potential use interference assessed.

3.2 SURFACE WATER INTAKES AND OUTFALLS (FIGURE 1):

Figure 1 also portrays the locations of municipal and industrial surface water intakes and outfalls.

The figure includes both potable water intakes for domestic use and unpotable water intakes which supply industrial users with process and/or cooling water. Outfall locations represent both industrial waste water discharges and municipal sewage treatment plant effluents.

The scale of this figure is too small to allow the plotting of every intake or every outfall; nonetheless, a general impression of relative intake and outfall densities in the study area may readily be gained. Particularly intensive municipal and industrial use of surface water is evident in Canadian waters of the St. Clair and Detroit Rivers and along the west and northwest shorelines of Lake Ontario.

3.3 SPAWNING AREAS (FIGURE 2):

The general locations of important lake spawning areas and spawning streams are illustrated on Figure 2.

While the figure suggests good data coverage on all of the Great Lakes, we have included many former spawning sites which today are not thought to be active for the species listed in some locations. For example, whitefish spawning sites in western Lake Ontario and in central Lake Erie may not be productive at present. Similarly all spawning sites for lake trout in Lake Huron are regarded as "former" sites. Nonetheless, we have included these locations with presently active sites in support of possible rehabilitation efforts for these species in the future.

Most permanent streams feeding the lower Great Lakes and Lake Huron support at least a limited run of rainbow trout and/or chinook or cohoe salmon. We have portrayed only those streams which are thought to support annual runs of over 200 fish in the spring.

Further more complete inventories of important fish species and spawning sites will be obtained once possible facilities options and locations have been identified.

4.0 EFFLUENT DISPERSION CONSIDERATIONS:

Safe discharge of an effluent to the surface water environment is dependent on a number of factors. In Chapter 3 we have red-flagged important surface water uses to ensure their protection. In this chapter, we will present basic information related to dilution capability of southern Ontario rivers and streams and discuss the dispersion of effluents within the coastal regions of the Great Lakes.

It is recognized that a complete assessment of effluent dispersion considerations requires detailed consideration of other factors such as effluent volumes and quality characteristics and the physical/chemical properties of the receiving water body. However, the information provided is useful at this preliminary inventory stage of the Facility Development Process and will aid in narrowing down possible systems options.

4.1 STREAMFLOW (FIGURE 3):

Our review of published information provided representative low streamflow characteristics in gauged reaches of southern Ontario streams and rivers. To provide an early indication of the capability of these streams to accept liquid effluents, low-flow dilution characteristics were assessed. It should not be construed that dilution in the receiving water body can be a substitute for treatment. Rather, the exercise provides a preliminary indication of the receiving stream's natural capability to buffer the effects of possible contaminants.

Since the size of a possible facility is not yet known, three different plant sizes were assumed for consideration as follows:

Small Facility	- discharging 10 L/s (±190,000 gallons per day)
Medium Facility	- discharging 25 L/s (±476,000 gallons per day)
Large Facility	- discharging 50 L/s (±950,000 gallons per day)

With these facility sizes in mind, five categories of representative minimum streamflow were selected with the objective of obtaining at least a ten parts streamflow to one part treated effluent (10:1) dilution ratio and at most, better than a 100:1 dilution ratio for even the largest assumed plant size. These five categories and corresponding ranges of dilution are provided in Table 1.

Table 1: Categories of representative minimum streamflow ranges with corresponding dilution ratios for three assumed liquid treatment facility sizes.

Category	Streamflow Range (L/s)	Dilution Ratio		
		Small Fac. (10 L/s)	Medium Fac. (25 L/s)	Large Fac. (50 L/s
1	<100	<1:1 to 10:1	<1:1 to 4:1	<1:1 to 2:1
2	101-500	10:1 to 50:1	4:1 to 20:1	2:1 to 10:1
3	501-1,000	50:1 to 100:1	20:1 to 40:1	10:1 to 20:1
4	1,001-5,000	100:1 to 500:1	40:1 to 200:1	20:1 to 100:1
5	>5000	>500:1	>200:1	>100:1

The larger gauged streams and rivers in southern Ontario are plotted on Figure 3. The minimum streamflow category within which each watercourse falls is presented. This facilitates a first-level screening of *natural* dilution capability under the critical low-flow period.

Table 1 shows that at least a 10:1 dilution ratio may be expected under low-flow periods for all plant sizes considered in water courses falling within the last three categories in Table 1. Figure 3 indicates that such flows are available in the major rivers connecting the Great Lakes along with considerable sections of the major inland streams such as the French, Saugeen, Thames, Grand, Trent and Mississippi.

4.2 GREAT LAKES COASTAL ZONE:

As is evident from Figure 1, discharge of treated waste water to the near-shore waters of the Great Lakes is common practice. Effluent discharges take the form of shoreline emissions into shallow water or submerged offshore discharges into deeper waters. The purpose of this section is to describe general transport and dispersion processes in the coastal zone and discuss the prediction of plume behaviour. It is based on a more detailed report submitted by Gore & Storrie Limited which is included as Appendix I.

Larger lakes can be divided into two main zones within which different transport and dispersion characteristics exist. The outer or "offshore zone" encompasses the main body of the lake while the nearshore or "coastal zone" extends in a narrow band around the perimeter of the lake. Lake circulation patterns, regulated mainly by wind and barometric pressure differences have been determined for the offshore zones of Lakes Ontario and Erie, Georgian Bay and portions of Lake Huron. Such patterns normally depict conditions under different wind directions and at different depths as shown in Figures 4 and 5. However, none of these long-term or mean current patterns apply to the coastal zone where most industrial and municipal effluents are discharged.

Transport and dilution in the coastal zone are likewise controlled by winds and barometric pressure but are also strongly influenced by local shoreline geometry, bathymetry and thermal density changes. Consequently, these processes vary with time and from location to location. Coastal currents which will carry effluent discharges may persist in one direction for several days followed by a period of reduced velocity and variable direction. The cycle may then be repeated but current direction may be reversed. Figure 6 shows a typical example of coastal current pattern. As well, the current speed and direction will also vary with depth as illustrated in Figure 7.

Coastal zone discharges *at shore* are transported and diluted by surface wave processes which are highly variable. Normally, these shore discharges have poor dilution due to shallow depths of water and the effluent may spread along the shoreline for great distances.

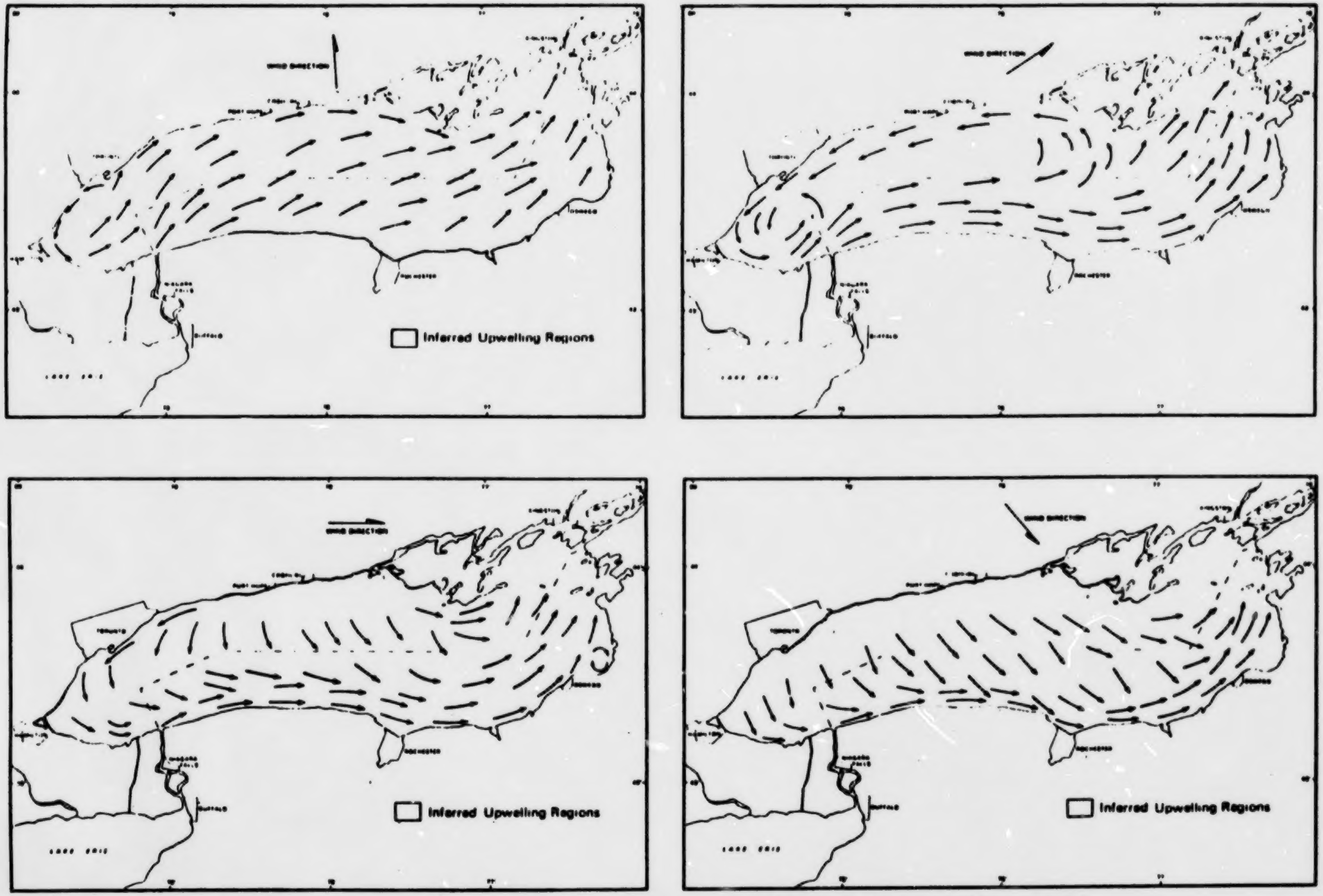
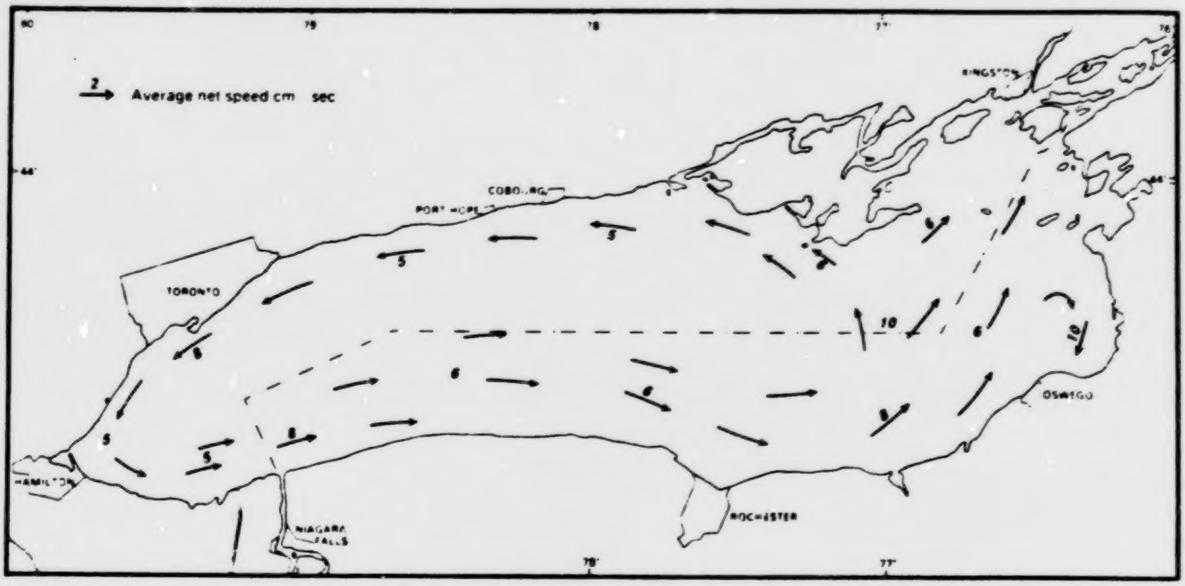
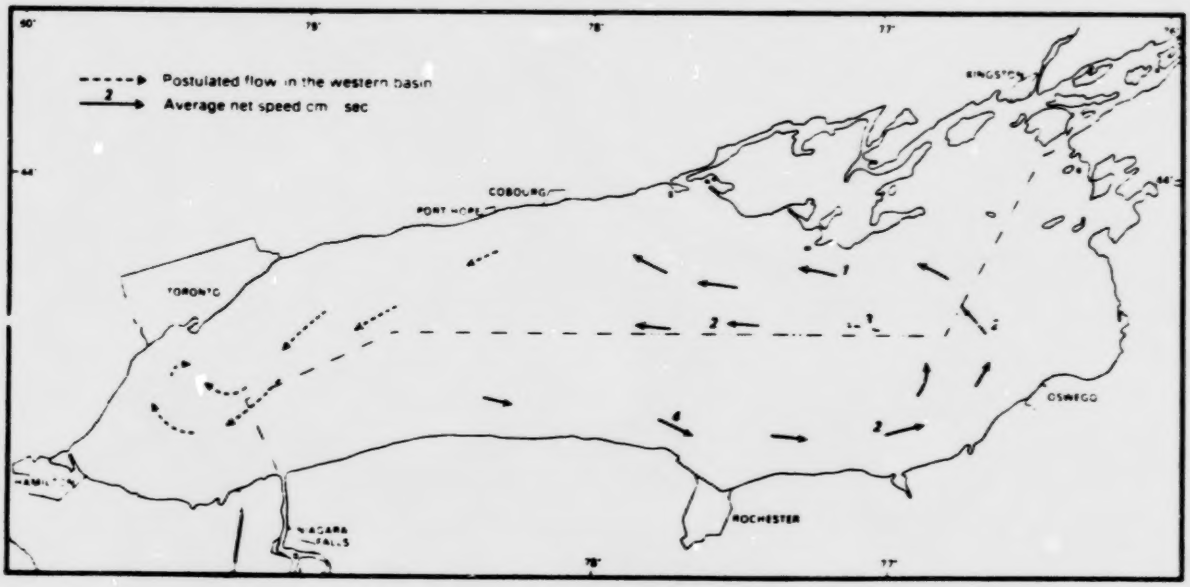

WIND DIRECTION
Inferred Upwelling Regions
WIND DIRECTION
Inferred Upwelling Regions
WIND DIRECTION
Inferred Upwelling Regions
WIND DIRECTION
Inferred Upwelling Regions

FIGURE 4 Surface circulation patterns under different wind conditions, 1967.
International Joint Commission, 1967 - Volume 3

(From: "Great Lakes as Receiving Waters" - Gore & Storrie Limited - 1982)

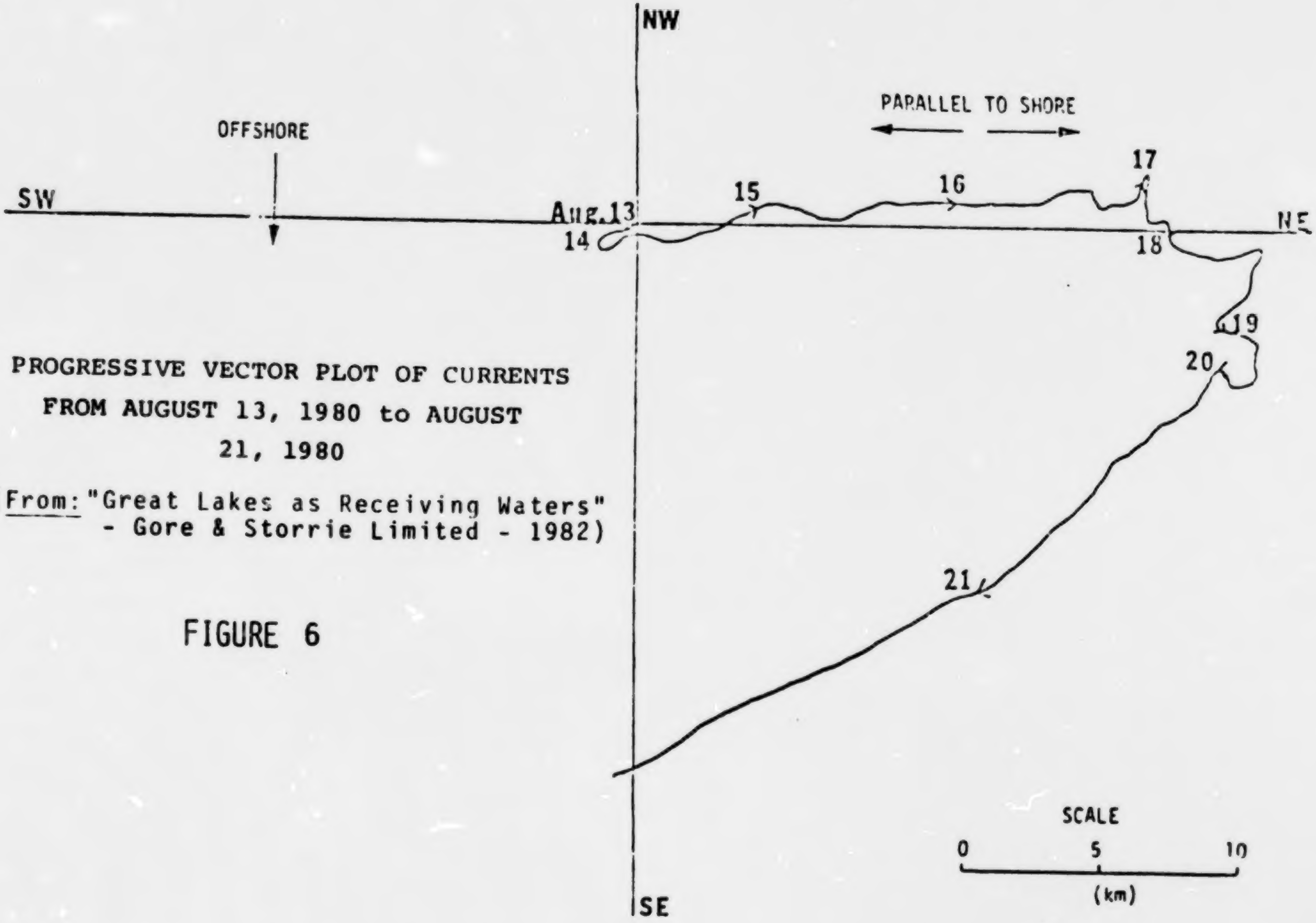

80°
79°
78°
77°
76°
44°
2
Average net speed cm sec
KINGSTON
COBOURG
PORT HOPE
TORONTO
OSWEGO
HAMILTON
NIAGARA FALLS
ROCHESTER
5
5
5
8
5
5
8
6
6
10
6
10
6
8
8

Mean circulation during period of summer stratification between 10 and 120 metres.


80°
79°
78°
77°
76°
44°
Postulated flow in the western basin
2
Average net speed cm sec
KINGSTON
COBOURG
PORT HOPE
TORONTO
OSWEGO
HAMILTON
NIAGARA FALLS
ROCHESTER
1
2
2
4
2

Mean circulation at depth greater than 120 metres during period of summer stratification.

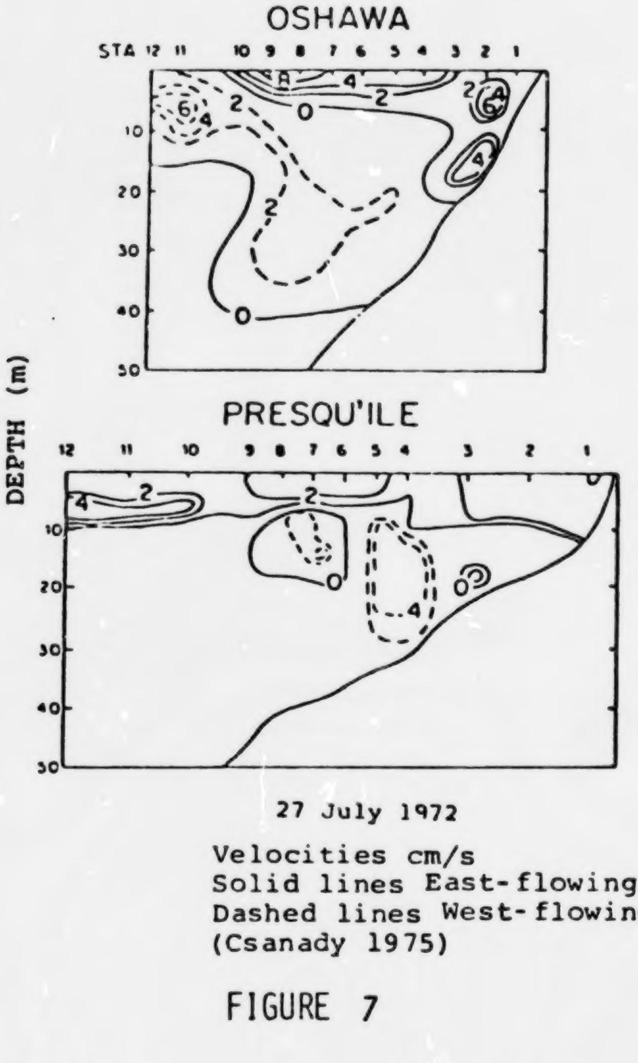
FIGURE 5: Mean Circulation - International Joint Commission, 1967 - Volume 3
(From: "Great Lakes as Receiving Waters" - Gore & Storrie Limited - 1982)



PROGRESSIVE VECTOR PLOT OF CURRENTS FROM AUGUST 13, 1980 to AUGUST 21, 1980

(From: "Great Lakes as Receiving Waters" - Gore & Storrie Limited - 1982)

FIGURE 6



27 July 1972

Velocities cm/s
Solid lines East-flowing
Dashed lines West-flowing
(Csanady 1975)

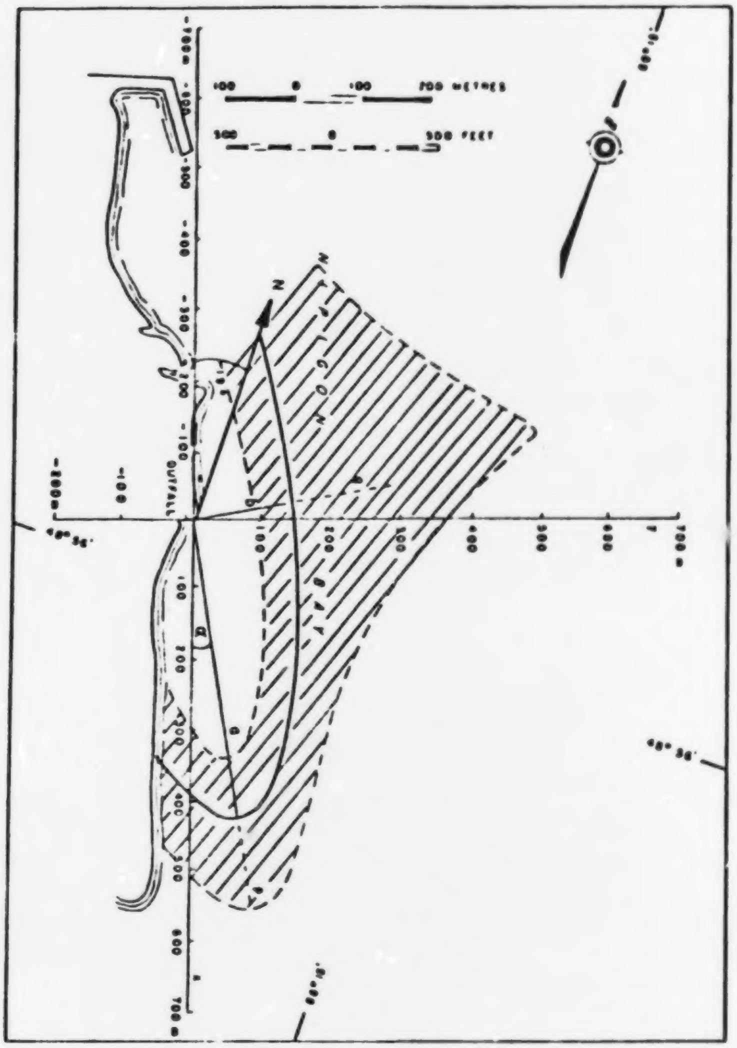
FIGURE 7

(From: "Great Lakes as Receiving Waters"
- Gore & Storrie Limited - 1982)

Coastal zone discharges *offshore* through a properly designed diffuser where depths are at least 10 cm can achieve consistently high dilution. This is generally the preferred method of discharging to the coastal zone.

Owing to the highly variable conditions especially close to shore in the coastal zone, concentration model predictions for a shore discharge presently can account for roughly 30 percent of measured variation. Figure 8 illustrates a typical prediction of a modelled shore discharge occurrence. Even this estimate requires local wave-wind data, shore geometry and bathymetry information.

For an offshore discharge in the coastal zone, mean monthly concentrations can be predicted reasonably well (see Figure 9). Hourly or daily local concentrations can be predicted well assuming steady-state conditions. These predictions require data on effluent density, quality and discharge velocity along with water quality, density stratification and current velocity in the receiving coastal zone location. However, for variable receiving water conditions and for discharges which remain near bottom, predictions are crude.


100 0 100 200 METRES
300 0 300 FEET
N
OUTFALL

SHORE DISCHARGE 95% ERROR BAND FOR MODEL
(Polak and Palmer 1977)

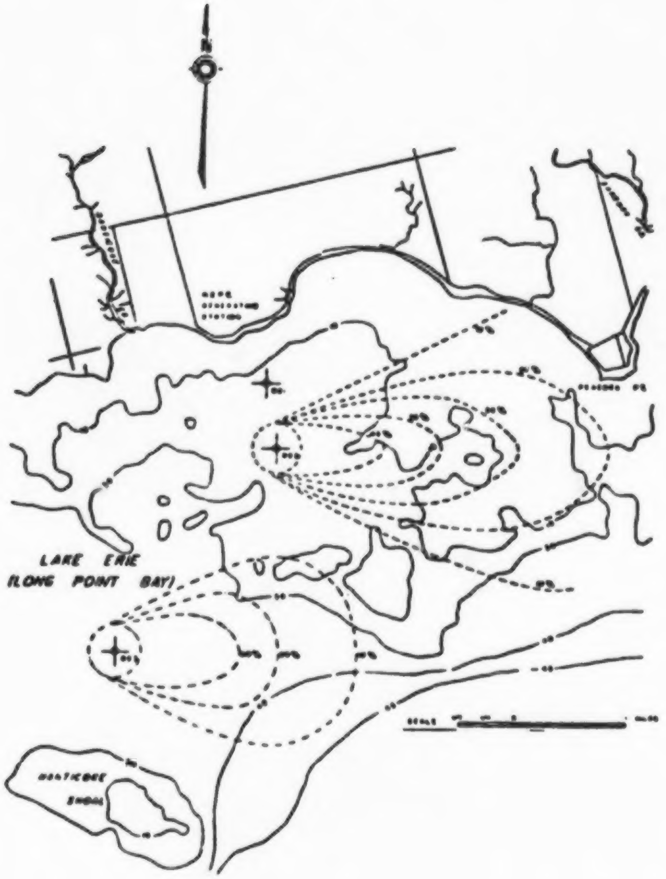
(From: "Great Lakes as Receiving Waters" -
Gore & Storrie Limited - 1982)

FIGURE 8

LEGEND

021 - submerged tower 1/3 depth
022 - surface tower mid. depth
023 - submerged tower mid. depth
— —·— ——— - September 1968 dispersion plum

NOTE: depth contour in feet



(Palmer & Izatt 1970)

FIGURE 9

(From: "Great Lakes as Receiving Waters" -
Gore & Storrie Limited - 1982)

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APPENDIX I

GREAT LAKES AS RECEIVING WATERS.

Submission by Gore & Storrie Limited, July 23, 1982

GREAT LAKES AS RECEIVING WATERS

The driving mechanisms for the currents in large lakes, except in the vicinity of large tributaries and outlets, are the winds and differences in barometric pressure. The resulting lake circulation patterns, however, are complex functions of lake geometry, bathymetry and density stratification in the summer. Because the wind climates vary with time, steady state conditions exist only for short periods of time. A detailed discussion of the lake hydrodynamics is presented by Clifford Mortimer (1974).

To conceptualize lake circulation patterns, plots are often produced which depict the lake currents for different wind conditions (see for example, Figures 1.1 and 1.2, from the International Joint Commission Report) and different depths (see for example, Figure 1.3 and 1.4). These representations are steady state, or mean conditions for a period of time, of the order of months. They are useful for long term transport calculations or long term mass balances for different sections of the lake. Detailed mean lake circulation plots are available for Lake Ontario and Lake Erie, with extensive data available for the Nanticoke area and the Western Basin. For Lake Huron circulation plots are available for Georgian Bay and Saginaw Bay and to a lesser extent for the Douglas Point area. For Lake Simcoe, there are no statistical circulation plots currently available.

None of the circulation diagrams apply to the coastal zone, where the depth of water decreases and the bottom friction affects begin to dominate the transport processes. The processes are further complicated by shoreline geometry restraints (for example, bays, points, shallow flats, etc.) and the effects of the wave interaction with the bottom and shore (called littoral processes) which may or may not be present at any particular time. Finally, density stratification effects are stronger in the coastal zone than farther offshore, because the density gradients are greater, which generates larger currents in the coastal zone. The effects of upwelling (colder, deeper offshore water rising to the surface) and downwelling (warmer near shore surface water sinking) and

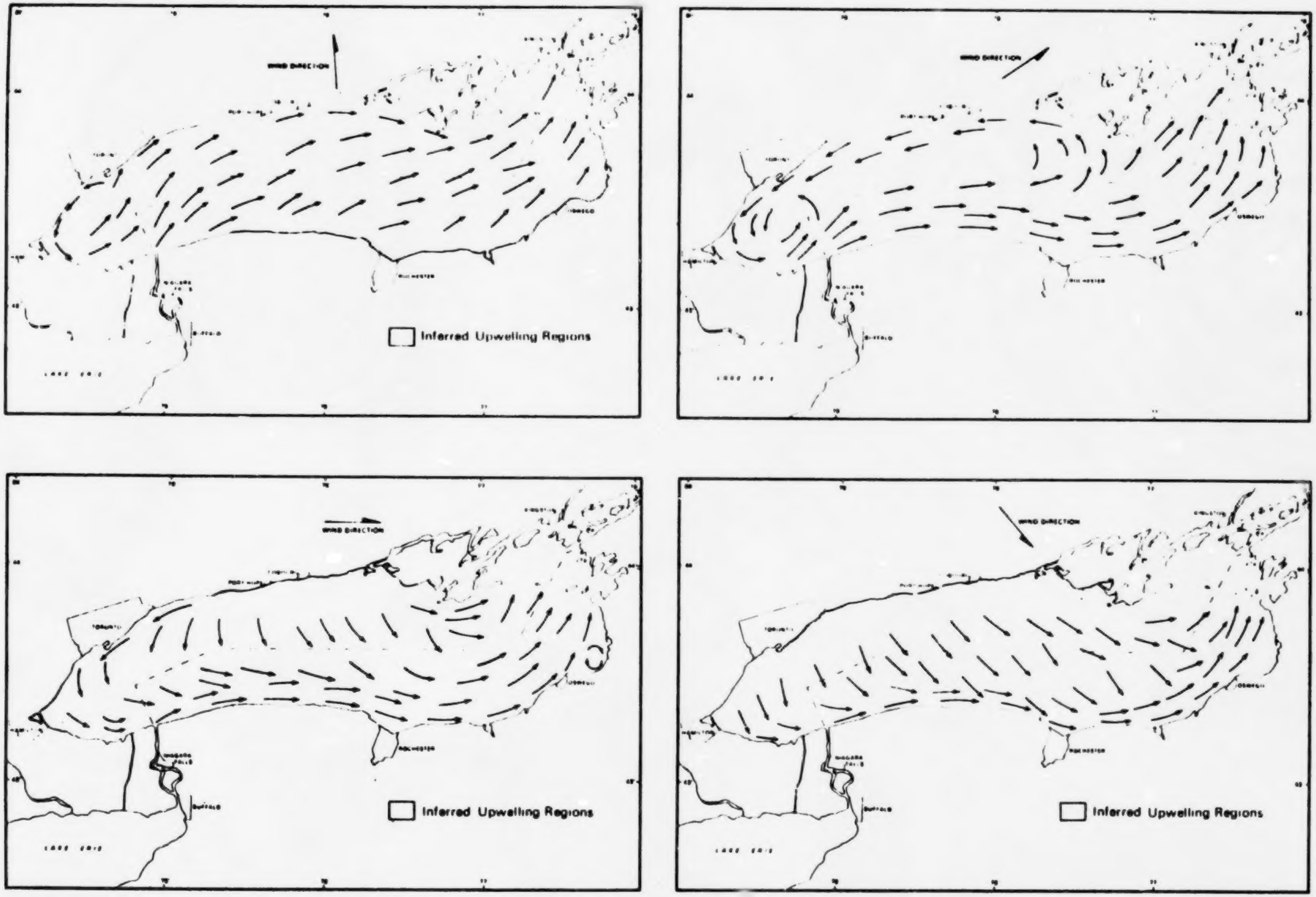

WIND DIRECTION
TORONTO
ROCHESTER
NIAGARA FALLS
BUFFALO
Inferred Upwelling Regions
WIND DIRECTION
Inferred Upwelling Regions
WIND DIRECTION
Inferred Upwelling Regions
WIND DIRECTION
Inferred Upwelling Regions

FIGURE 1.1 Surface circulation patterns under different wind conditions, 1967.

(From: International Joint Commission, 1967 - Volume 3)

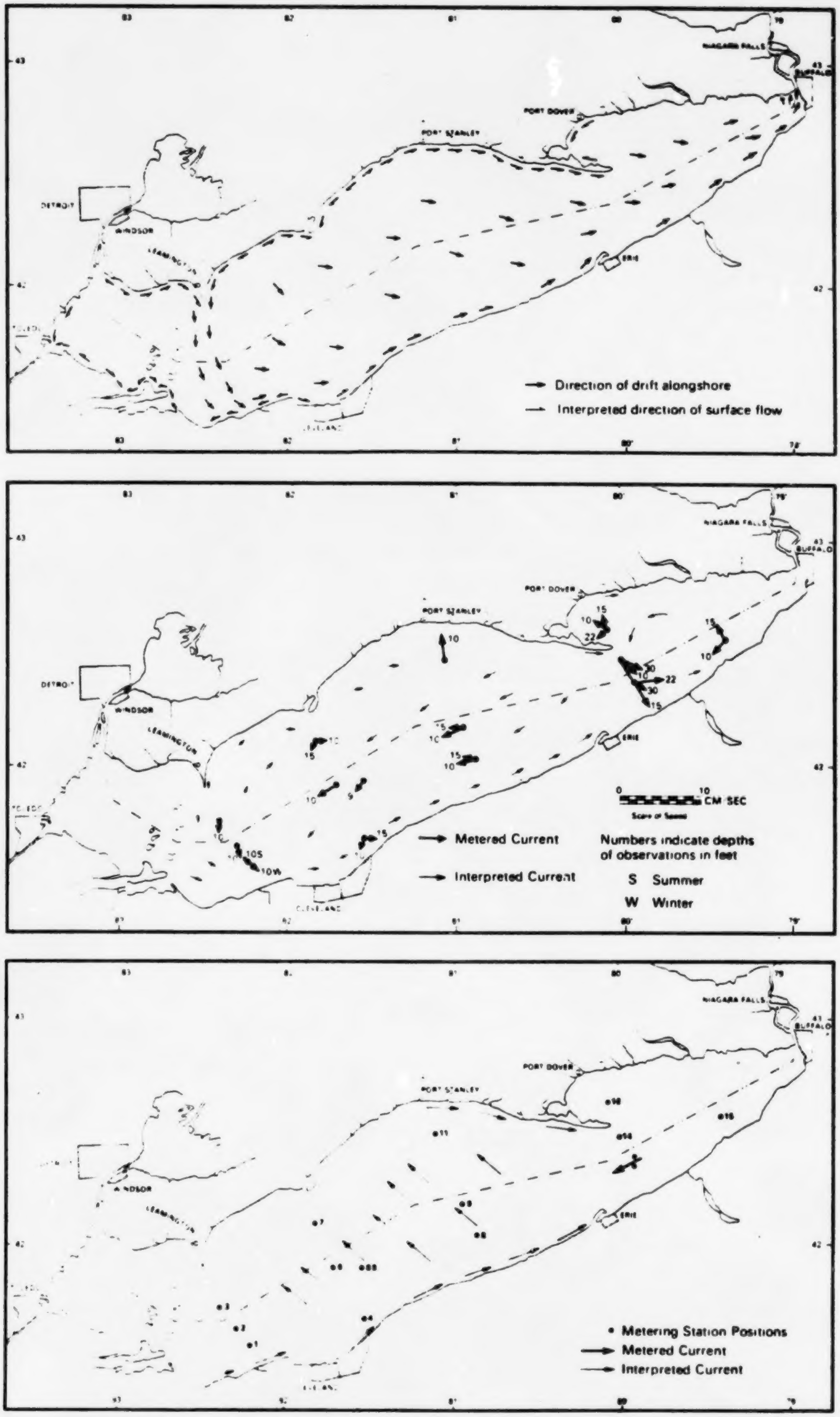
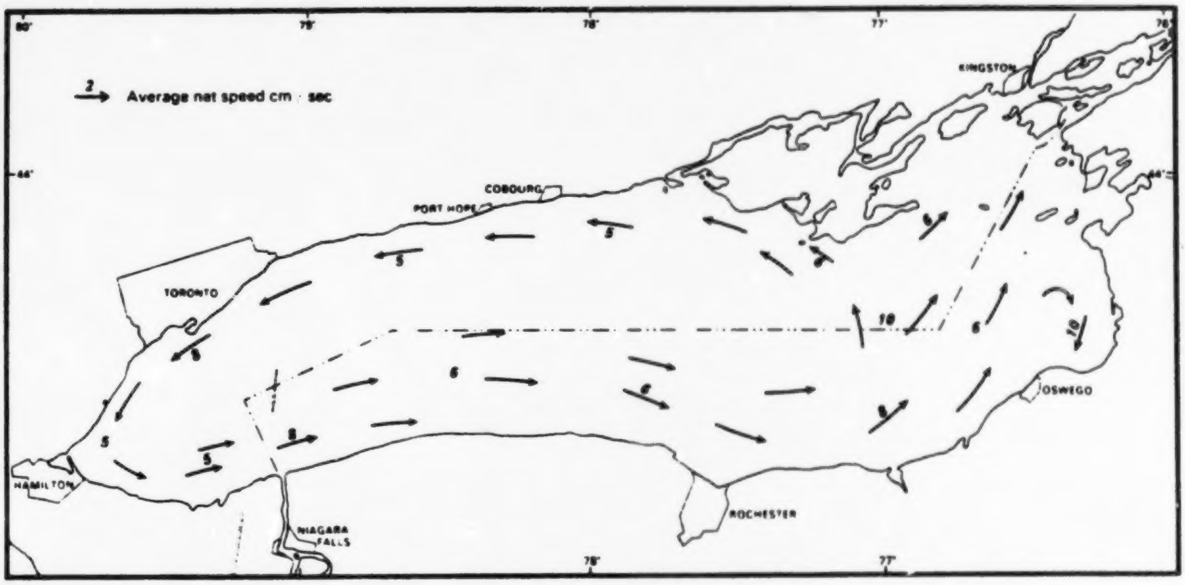
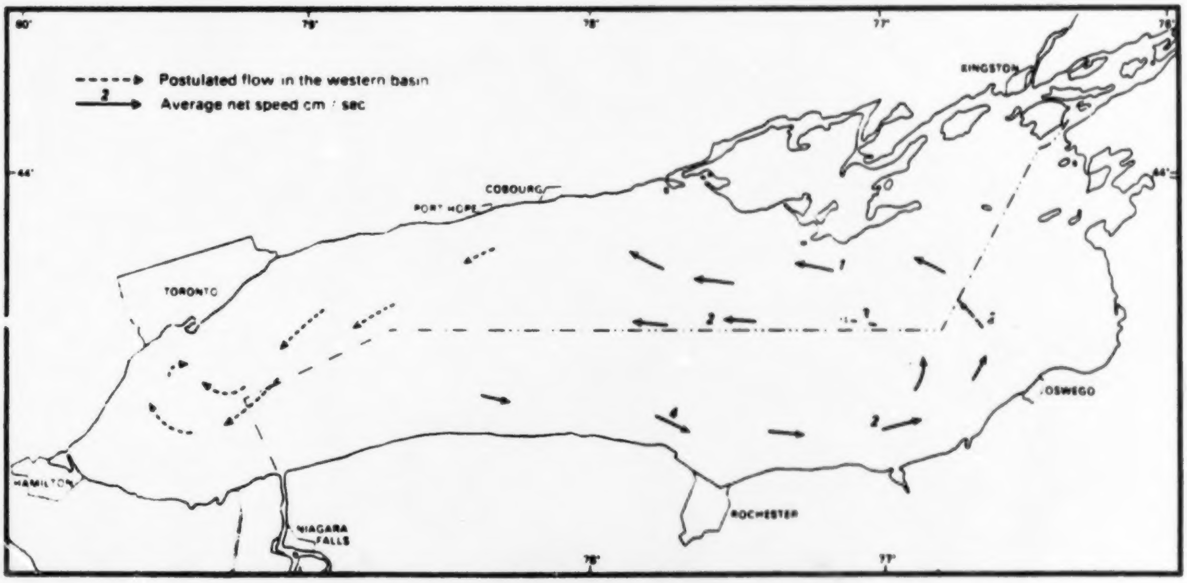

NIAGARA FALLS
BUFFALO
PORT DOVER
PORT STANLEY
DETROIT
WINDSOR
LEAMINGTON
TOLEDO
ERIE
CLEVELAND
Direction of drift alongshore
Interpreted direction of surface flow
Metered Current
Interpreted Current
Numbers indicate depths of observations in feet
S Summer
W Winter
0 10 CM SEC
Scale of Speed
Metering Station Positions
Metered Current
Interpreted Current

FIGURE 1.2 Dominant features of the surface, intermediate and bottom circulation in the central and eastern basins of Lake Erie. (From: International Joint Commission, 1967 - Volume 2)



80°
79°
78°
77°
76°
44°
2 Average net speed cm / sec
KINGSTON
COBOURG
PORT HOPE
TORONTO
HAMILTON
NIAGARA FALLS
ROCHESTER
OSWEGO

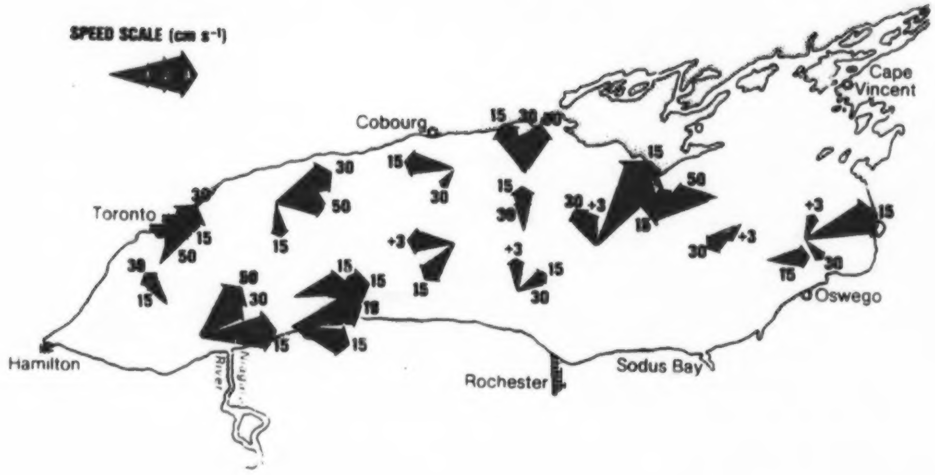
Mean circulation during period of summer stratification between 10 and 120 metres.



80°
79°
78°
77°
76°
44°
Postulated flow in the western basin
2 Average net speed cm / sec
KINGSTON
COBOURG
PORT HOPE
TORONTO
HAMILTON
NIAGARA FALLS
ROCHESTER
OSWEGO

Mean circulation at depth greater than 120 metres during period of summer stratification.

FIGURE 1.3 : Mean Circulation - International Joint Commission, 1967 - Volume 3


SPEED SCALE (cm s-1)
Cape Vincent
Cobourg
Toronto
Hamilton
Niagara River
Rochester
Sodus Bay
Oswego

Lake Ontario observed currents (depths in metres at arrow tips: +3 indicates 3 m off bottom) vector averaged from June through October 1972. (Pickett & Bermick 1977)

FIGURE 1.4

pronounced effects of the movement of the spring thermalbar, which acts as a density barrier, limiting water movement between the shore and the lake. All these processes are time variant.

The region of the coastal zone closest to shore (to where water depths are approximately 4.1 m) called the littoral zone, is the part of the coastal zone where the surface waves generate the transport and dispersion. The characteristics of the littoral zone and the coastal zone are discussed subsequently, separately.

Two types of discharges will be considered. A discharge at the shore consisting of rivers or creeks, non-point source runoff and man-made point sources is one type. The shore discharges are in the littoral zone of the coastal zone. The transport and dispersion in the littoral zone are most intense during an active wave period but because waves are periodic, and water depths small, discharges to the littoral zone generally affect extensive lengths of shoreline. The second type is an offshore submerged discharge. These discharges are primarily affected by the coastal boundary layer processes. Offshore submerged discharges can achieve large, consistent magnitude dilution provided a properly designed diffuser is located in deep enough water.

An important consideration for any discharges to the coastal zone is the existing water use in that zone. Presently, most water supply intakes and waste discharge outfalls are in the coastal zone and the littoral zone is used in some areas for body contact recreation. The coastal zone also supports the fish population by providing the habitat for young-of-the-year (littoral zone), spawning areas (coastal boundary layer), feeding area (coastal boundary layer) and migration media (coastal boundary layer).

LITTORAL ZONE HOURLY PROCESSES

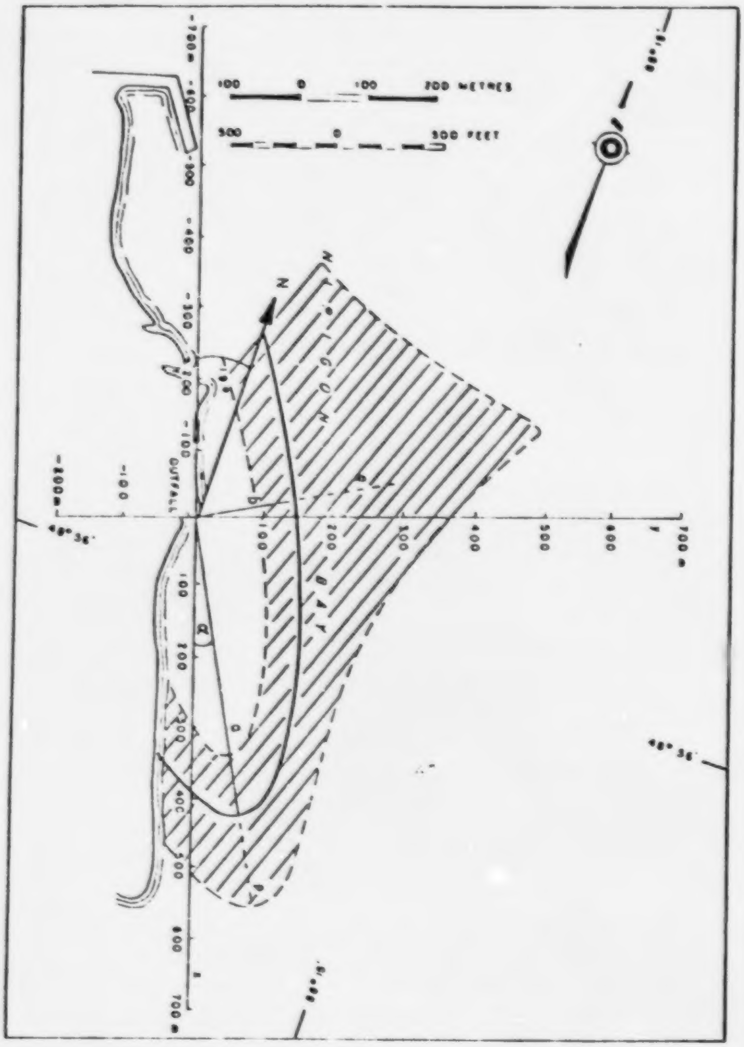
The interaction of the waves and shoreline/bottom topography dominate the transport, dilution and dispersion processes in the littoral zone. Generally, the response of waves to winds occurs quickly and a subsequent generation of the littoral drift currents and mixing is rapid. However, there is a time lag between wind cessation and wave die-down as inertial energy is dissipated. The littoral drift circulation patterns develop and stop quickly; consequently, a time-scale for these processes is hours. Extensive periods of time can occur when the circulation due to littoral drift is minimal. The currents, dispersion and sediment transport due to littoral drift are highly variable and are direct functions of wind speed, direction and duration and can obviously be zero for extended periods of time. Some portions of the littoral zone may have a net transport in one direction due to the prevailing wind direction and shoreline composition and geometry resulting in sediment accumulation or erosion at different locations.

In general, the dilution capacity of the littoral zone is less than farther offshore because there is less water depth available for mixing and the periodically generated currents and dispersion are highly variable.

Presently the littoral drift current and dispersion models are generated from the sediment transport equations and have comparable precision. Extensive data are available on sediment transport for the Great Lakes (see for example, Cook, 1970; Coakley 1972 and 1973; Greenwood and McGillivray, 1978; David-Arnott and Pollard, 1980). There are numerous programs available to predict sediment transport, using one or some of the following: wind, tide, wave height, wave steepness and wave power. Eight of these models were compared with field measurements by Seymour and King (1982). The best performance by any model had a correlation coefficient squared 0.35. In other words, the models could at best only explain one-third of the measured variation. A recent wave energy program by Tanner (1974) is promising but was not included in the review by Seymour and King (1982).

Recently, some mathematical equations for the dispersion due to waves had been developed from laboratory studies (Ergin 1980) and theoretical studies with some field validation (Ostendorf 1982). Ostendorf indicates a correlation coefficient squared of 0.25 for a limited data set.

In conclusion the existing methods for predicting littoral currents and dispersion can presently account for approximately one-third of the measured variations. Figure 1.5 shows the large errors in the predictions for the shore discharge.


100 0 100 200 METRES
500 0 500 FEET
N
BAY
OUTFALL
α
-200 m
-100
100
200
300
400
500
600
700 m
-700 m
-600
-500
-400
-300
-200
-100
48°36'
48°36'

SHORE DISCHARGE 95% ERROR BAND FOR MODEL
(Polak and Palmer 1977)

FIGURE 1.5

COASTAL BOUNDARY LAYER

The coastal boundary layer is the transient zone between the shoreline and main body of the lake. The shore geometry and bathymetry influence the processes in the coastal boundary layer. For effluent discharge to the coastal zone we will discuss the processes effective in the time-scales of hours, days and months. The processes we wish to review are dispersion or dilution, density stratification and transport.

Motions in the Great Lakes are primarily caused by winds and subsequent changes in water level and density gradients. These motions are not simple relationships of wind direction, magnitude and persistance in the coastal zone due to the constraints of the local shoreline and the bathymetry. In the main body of the lake, the lake thermally divides into a surface (epilimnion) and a deep layer (hypolimnion) during the spring to fall period.

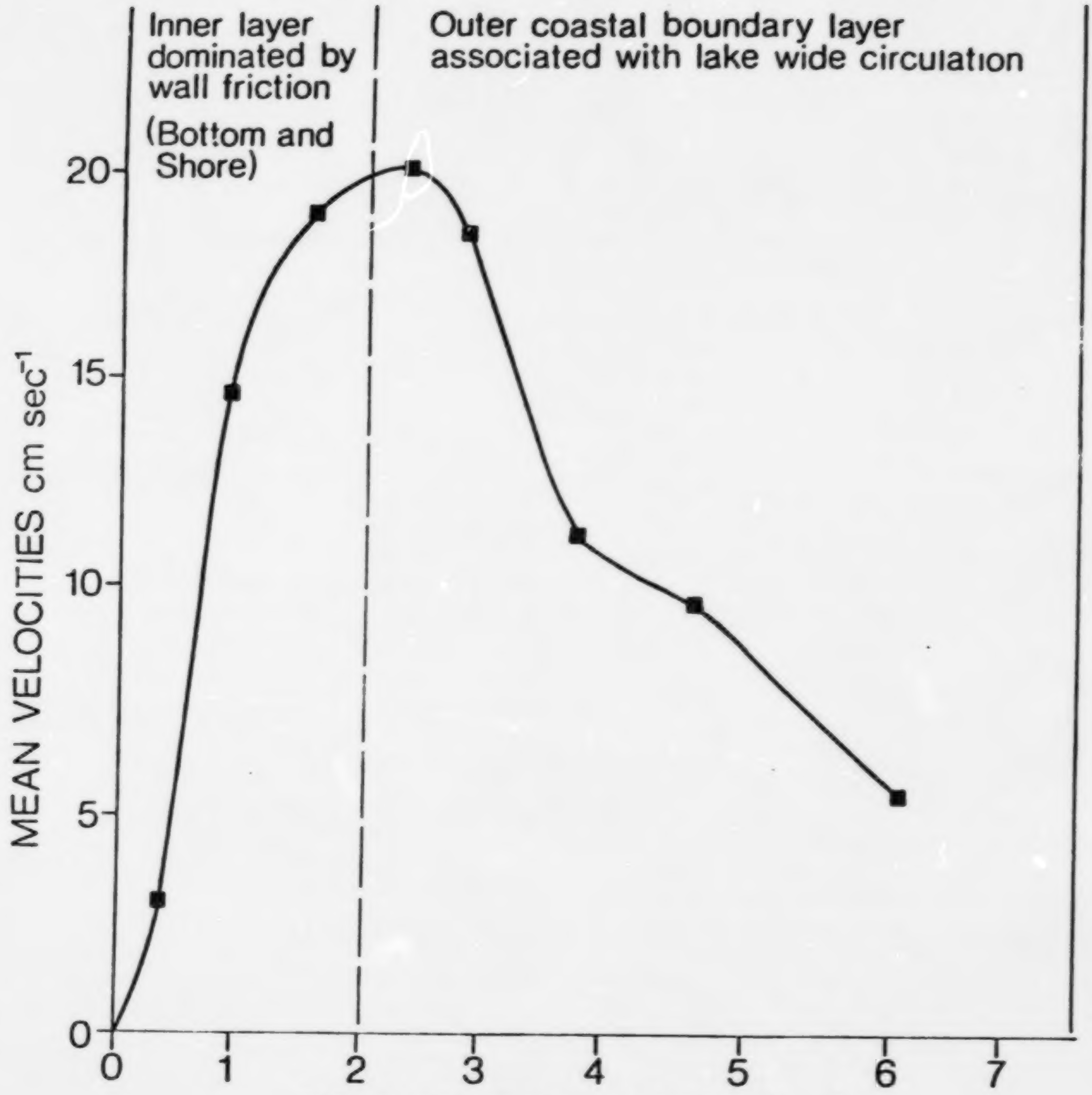
Monthly Time-Scale Phenomena

Velocity data from coastal zone studies in the Oshawa and Douglas Point area can be statistically summarized (see Figure 1.6). Predictions of average conditions can be made by using these data in combination with the statistical ranges of horizontal and depth dispersion coefficient data (see Figure 1.7) for the coastal zone. A general coastal zone dilution relationship is that dilution is approximately directly proportional to distance (Csanady 1970).

Hourly and Daily Time-Scales

Coastal Dispersion After Outfall Dilution

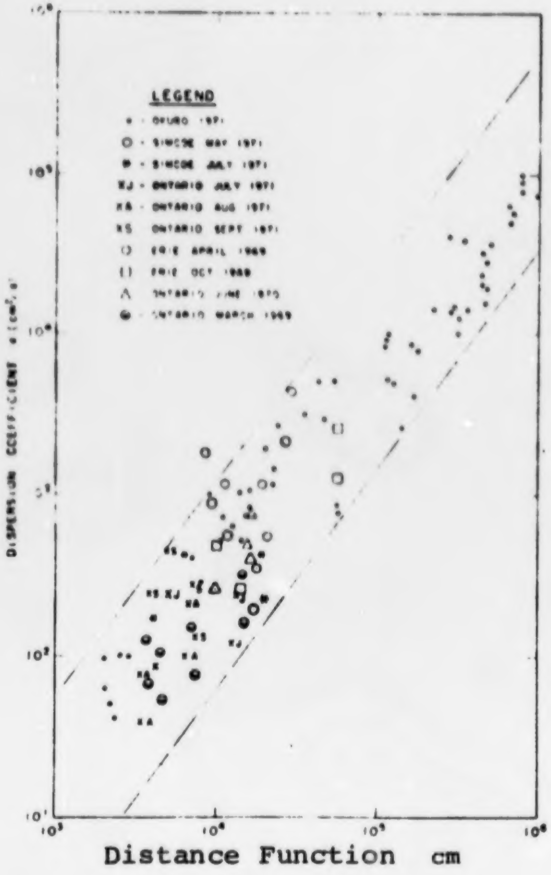
Hourly and daily predictions in the coastal zone require the consideration of the periodic events. Currents in the coastal zone generally persist in one direction, normally parallel-to-shore, for several days, followed by a period of varying length when the currents are reduced in magnitude and variable in direction. The cycle is then repeated, although the current direction may be reversed. Figure 1.8 shows a typical example of the coastal current pattern. The magnitude of the current is a local variable but has a



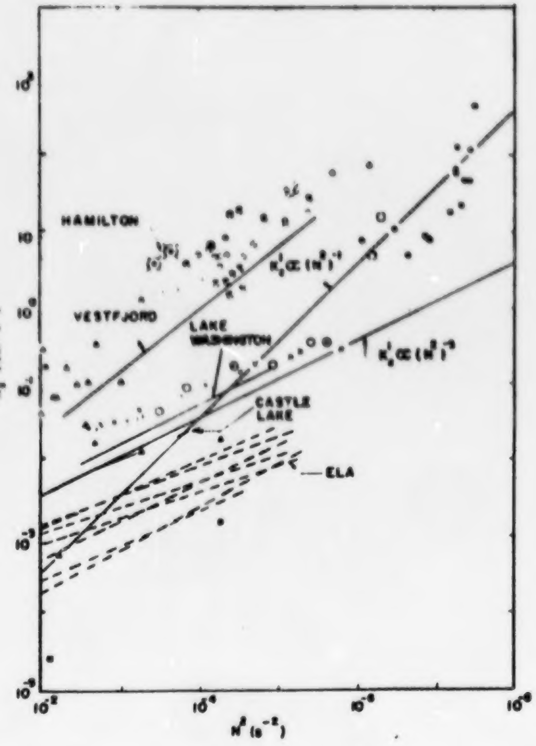
(BOYCE & LAM 1978)

Jul 29 - Aug 9, 1974

FIGURE 1.6

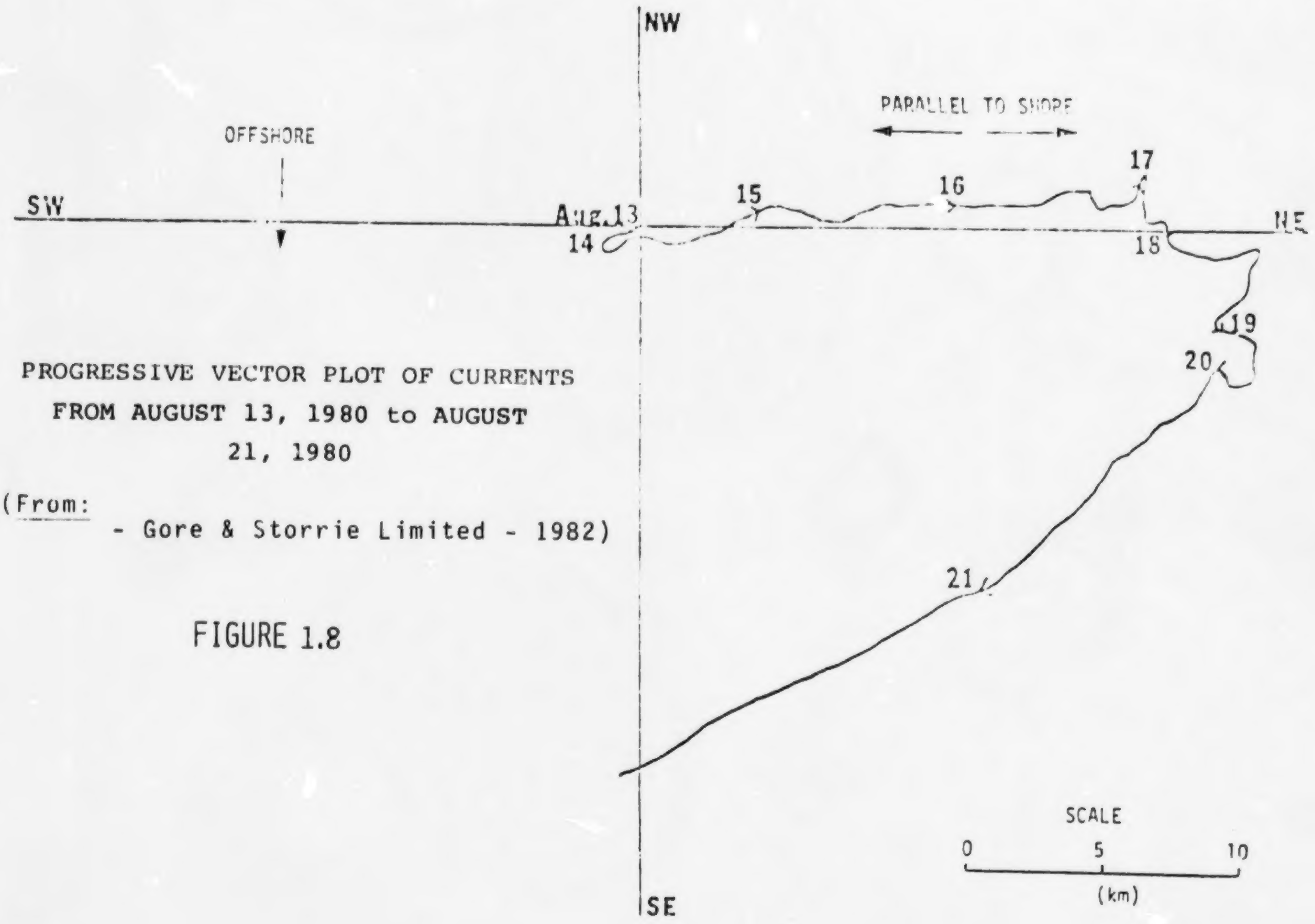


Dispersion coefficients and distance function (Palmer, 1976)



Vertical eddy diffusion rates (K^1_2) and stabilities (N^2) (Quay et al. 1980) (Palmer, 1981)

FIGURE 1.7



PROGRESSIVE VECTOR PLOT OF CURRENTS
FROM AUGUST 13, 1980 to AUGUST
21, 1980

(From:
- Gore & Storrie Limited - 1982)

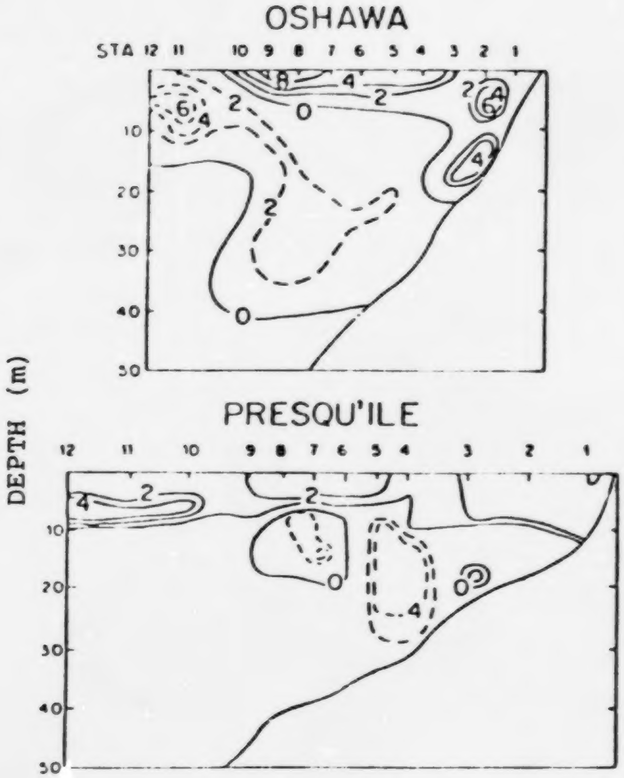
FIGURE 1.8

general statistical functional relationship with distance from shore (see Figure 1.6). There is also variability with depth as shown in Figure 1.9. For a current persistent in one direction it is possible to predict concentrations using the current velocity and dispersion data in one or two-dimensional equations (see Figure 1.10 and Palmer 1977). However, methods for predicting dispersion through the variable current and reversal of direction shown in Figure 1.8 are, at best, crude. One of the major problems is estimating receiving water background concentrations during non-steady state currents, particularly for the zero current condition.

If a discharged effluent is buoyant in the receiving water, special oil slick models like Tayfun and Wang (1973) can be used. If a discharged effluent sinks to the bottom, there are only crude first-order approximations available to predict the plume concentrations.

Outfall Dilution

The predictions of the plume from a submerged offshore discharge are well developed and have been verified with some field measurements. These models consider the density of the effluent, density gradient of the receiving water, currents in the receiving water and the velocity of discharge. Figure 1.11 shows a typical example. Good models exist for predicting the effluent plumes from single and multiple jet outfalls of the alternating, staged and tee-type diffusers (Ditmars 1969: Almquist and Stolzenbach 1980: McEnroe and Jain 1980). It is also possible to input receiving water current direction and estimate the effluent plume bottom contact distance (Roberts 1979). All these predictions are for steady-state conditions, for example for constant effluent velocity and density and constant receiving water density gradient and velocity. Consequently, the predictions through variable currents and reversal of direction shown in Figure 1.8 are crude as it is necessary to do a series of runs for each different set of values and determine the range of resulting dilutions for these conditions.



27 July 1972

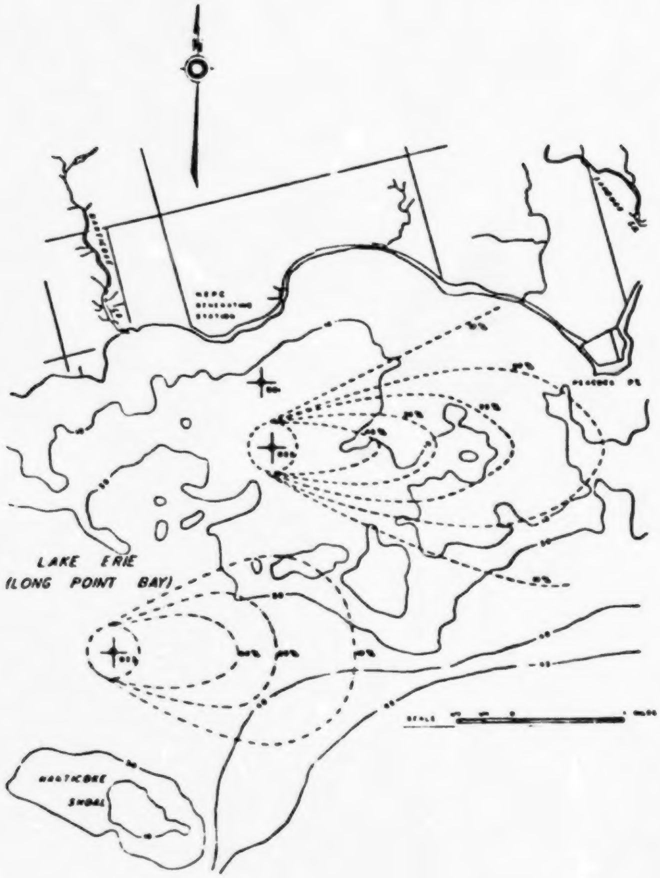
Velocities cm/s
Solid lines East-flowing
Dashed lines West-flowing
(Csanady 1975)

FIGURE 1.9

LEGEND

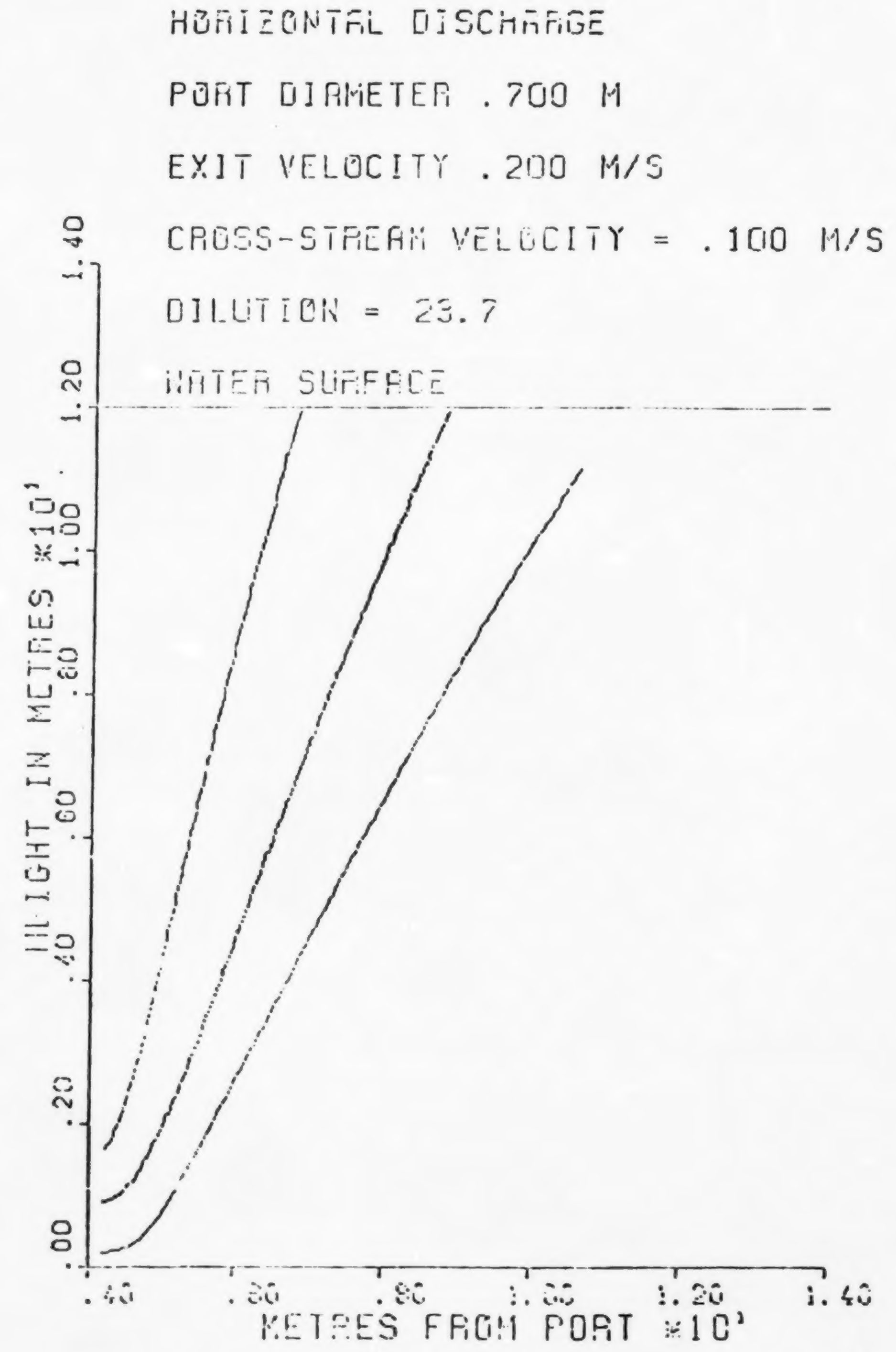
021 - submerged tower 1/3 depth
022 - surface tower mid. depth
023 - submerged tower mid. depth
– – – – - September 1968 dispersion plume

NOTE: depth contour in feet


N
LAKE ERIE
(LONG POINT BAY)
NANTICOKE
SHOAL

(Palmer & Izatt 1970)

FIGURE 1.10



(GORE & STORRIE 1982)

FIGURE 1.11

SUMMARY

The transport and dilution in the coastal zones are controlled by winds and differences in barometric pressure on the lake surface. Consequently, both the transport and dilution in the coastal zone vary with time. These processes are strongly influenced by local shoreline geometry and bathymetry. Consequently, they vary from location to location. Coastal zone discharges at shore are transported and diluted by surface wave processes which are highly variable in both time and location on the shore. Normally, the shore discharges have poor dilution due to the shallow depths of water and the effluent spreads along the shore for great distances. Offshore discharges, through a properly designed diffuser in the coastal zone where water depths are at least 10 m, can achieve consistently high dilutions and is the generally preferred method of discharging to the coastal zone. Some special considerations are required for the outfall when the lake is thermally stratified or when the effluent discharged rises to the surface or sinks to the bottom.

PREDICTION TECHNIQUES

Littoral Zone

Concentration model predictions for a shore discharge presently can only account for approximately 30 percent of the measured variation. Even this estimate requires local wave-wind data, shore geometry and bathymetry.

Coastal Zone

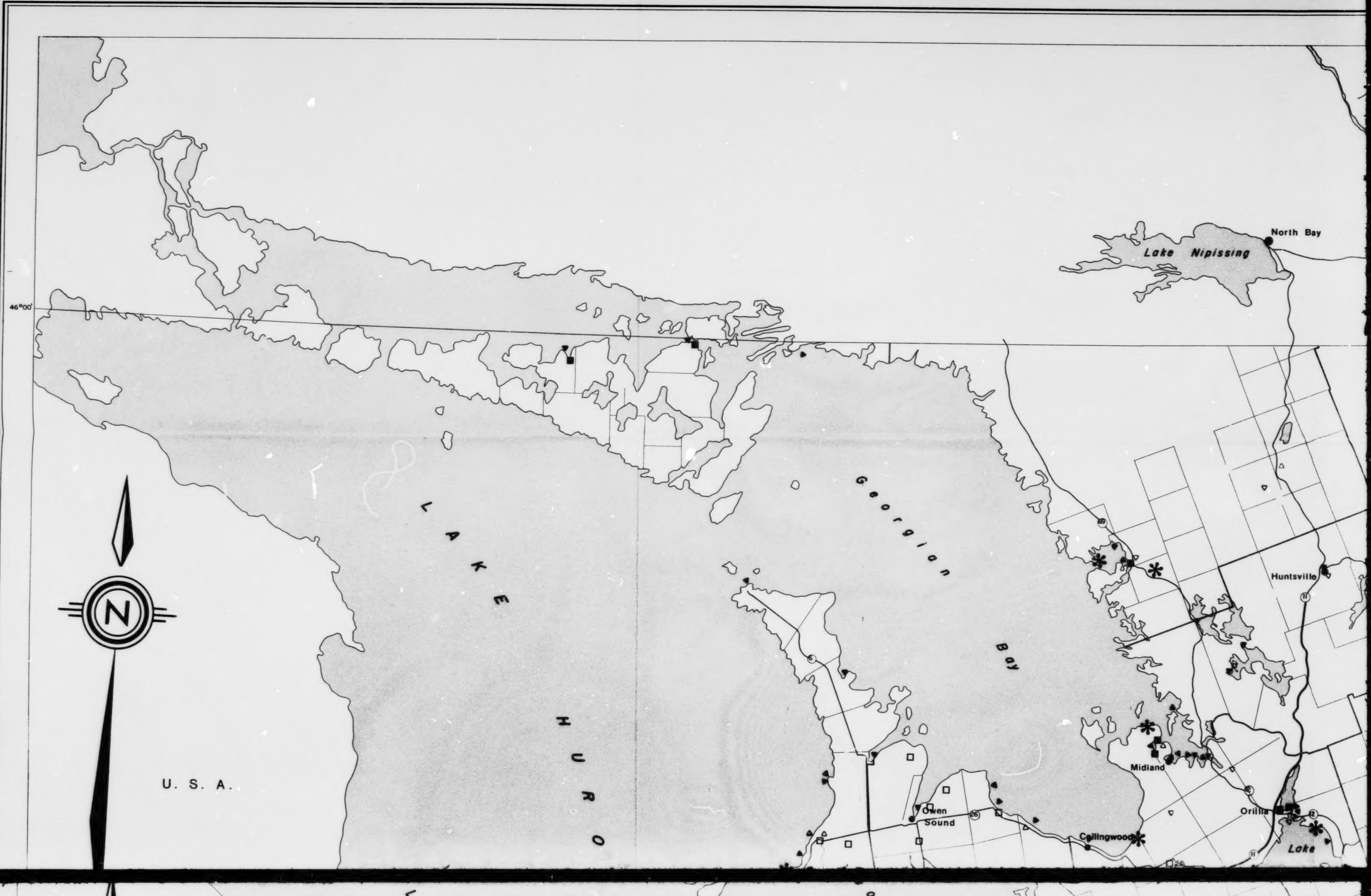
Mean monthly concentrations for an offshore discharge can be predicted reasonably well with the available data.

The hourly or daily local concentrations from a submerged discharge in the coastal zone can be predicted well for steady-state conditions. The prediction requires data on the effluent density, quality and velocity and on the receiving water quality, density stratification and current velocity. For variable receiving water conditions, the predictions are crude.

The hourly or daily concentrations after the initial dilution from the outfall diffuser is completed can be predicted for steady-state conditions. However, some local data on local current profiles are required. The prediction models can only approximate variable conditions by treating the event as a series of different steady-state conditions.

The hourly concentrations for a substance on the surface can be made provided data are available on surface currents and winds.

Methods for predicting hourly or daily concentrations of a substance that remains near the bottom are crude and require local density gradient data and the depth velocity profiles.



North Bay
Lake Nipissing
46°00'
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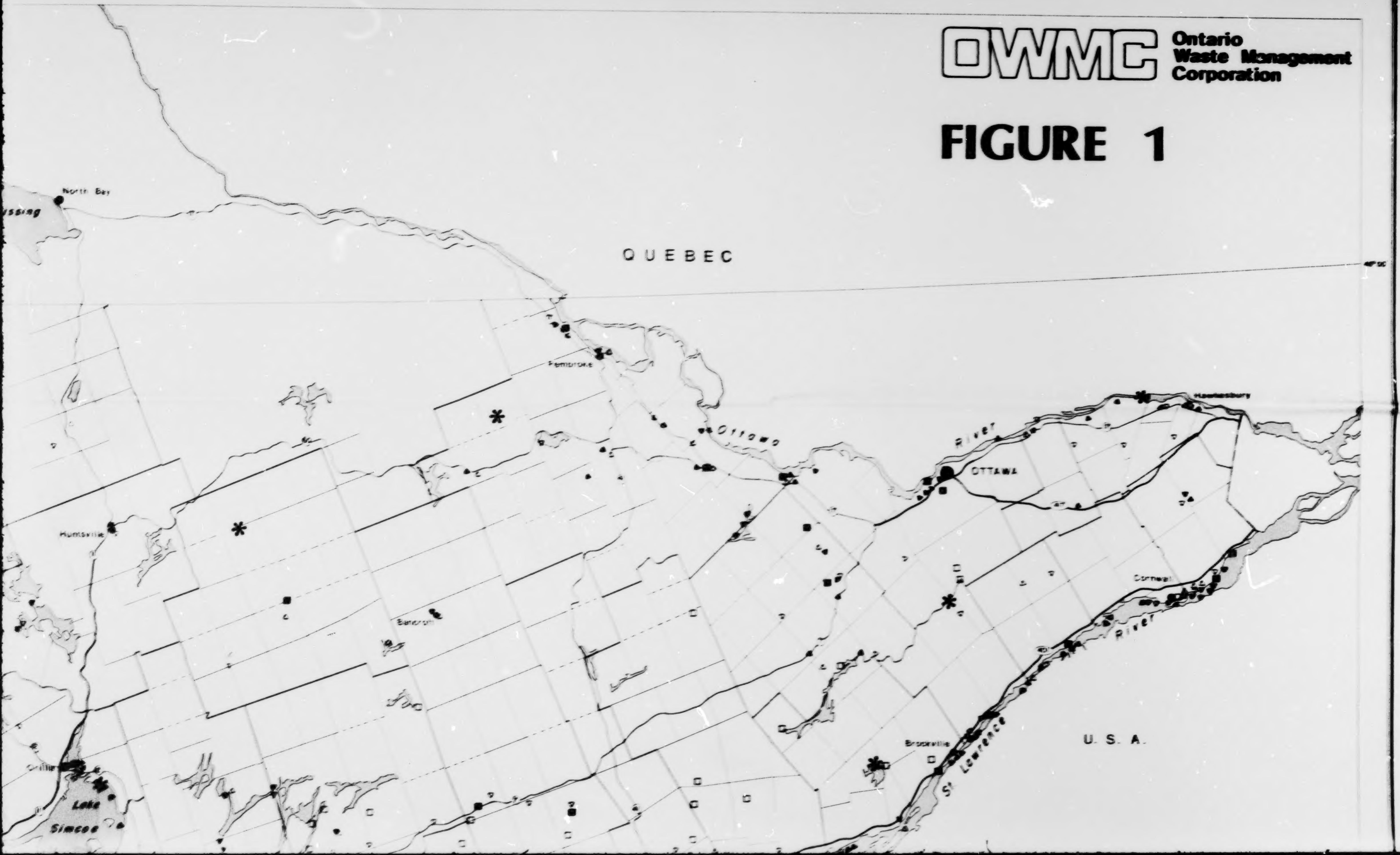
LAKE HURO
Georgian Bay
U. S. A.
Huntsville
Midland
Owen Sound
Collingwood
Orillia
Lake
69
11
26
6
12

Ontario Waste Management Corporation

FIGURE 1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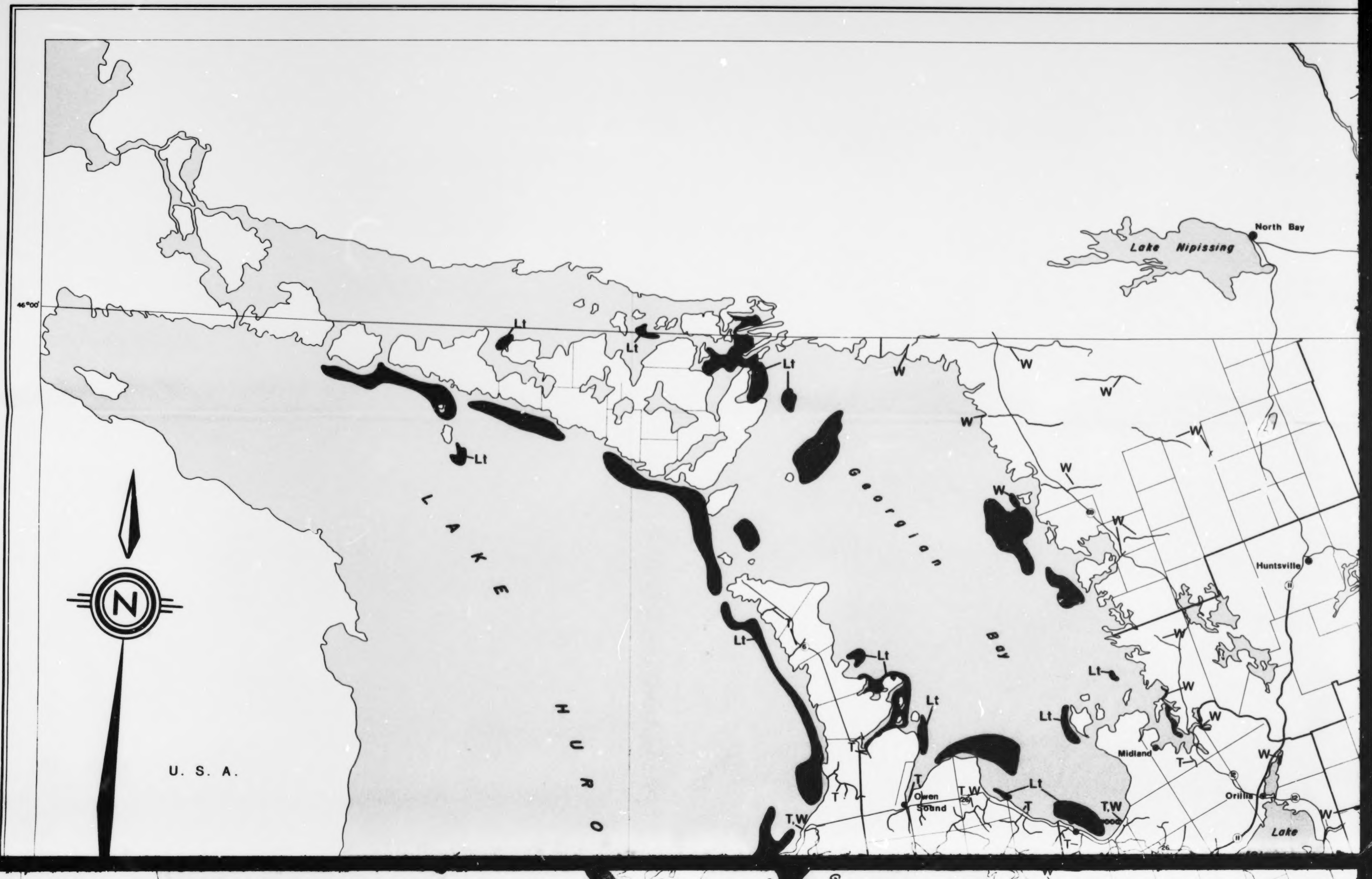
St Lawrence
Orillia
Lake
Simcoe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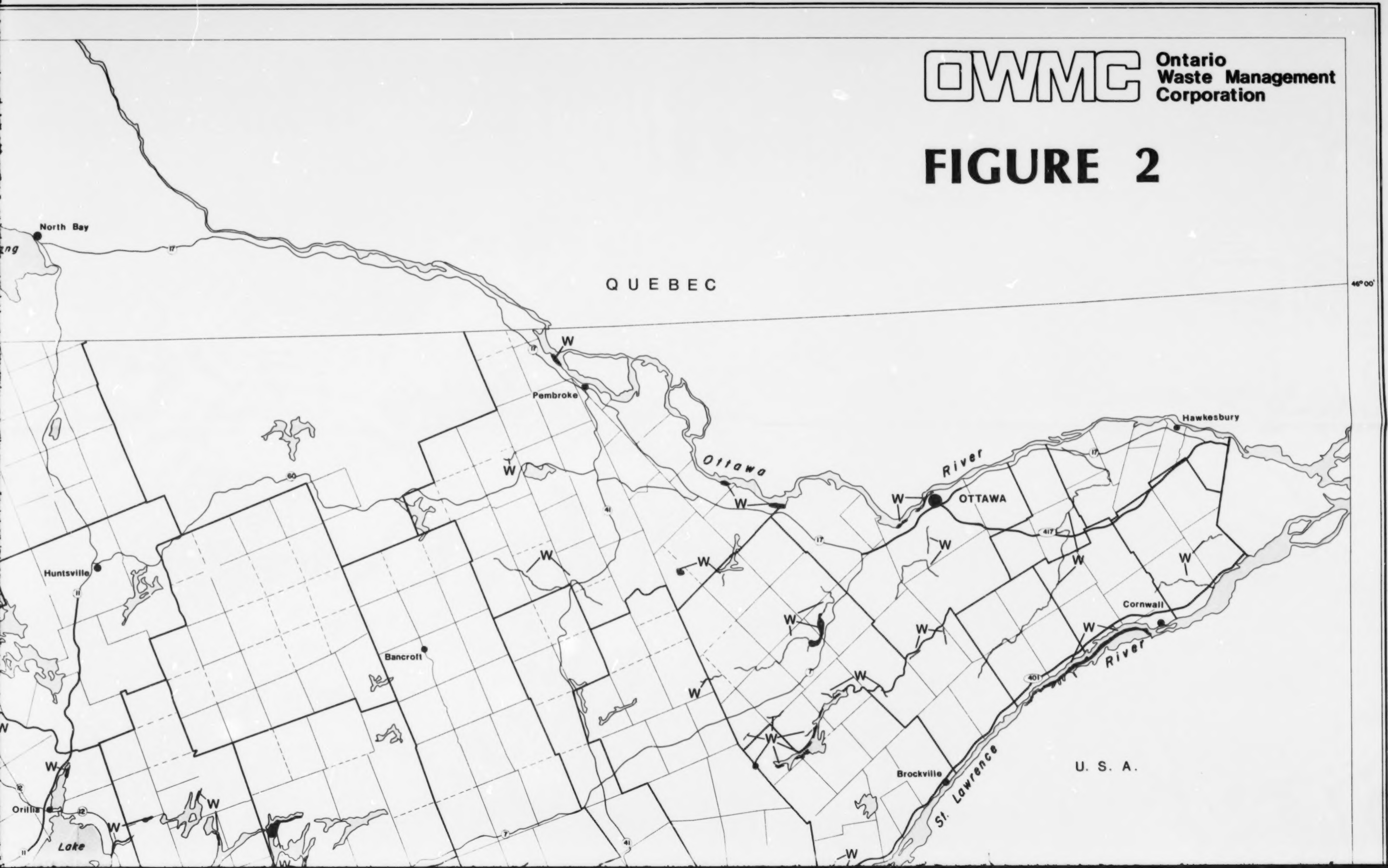
OWMC Ontario Waste Management Corporation

FIGURE 2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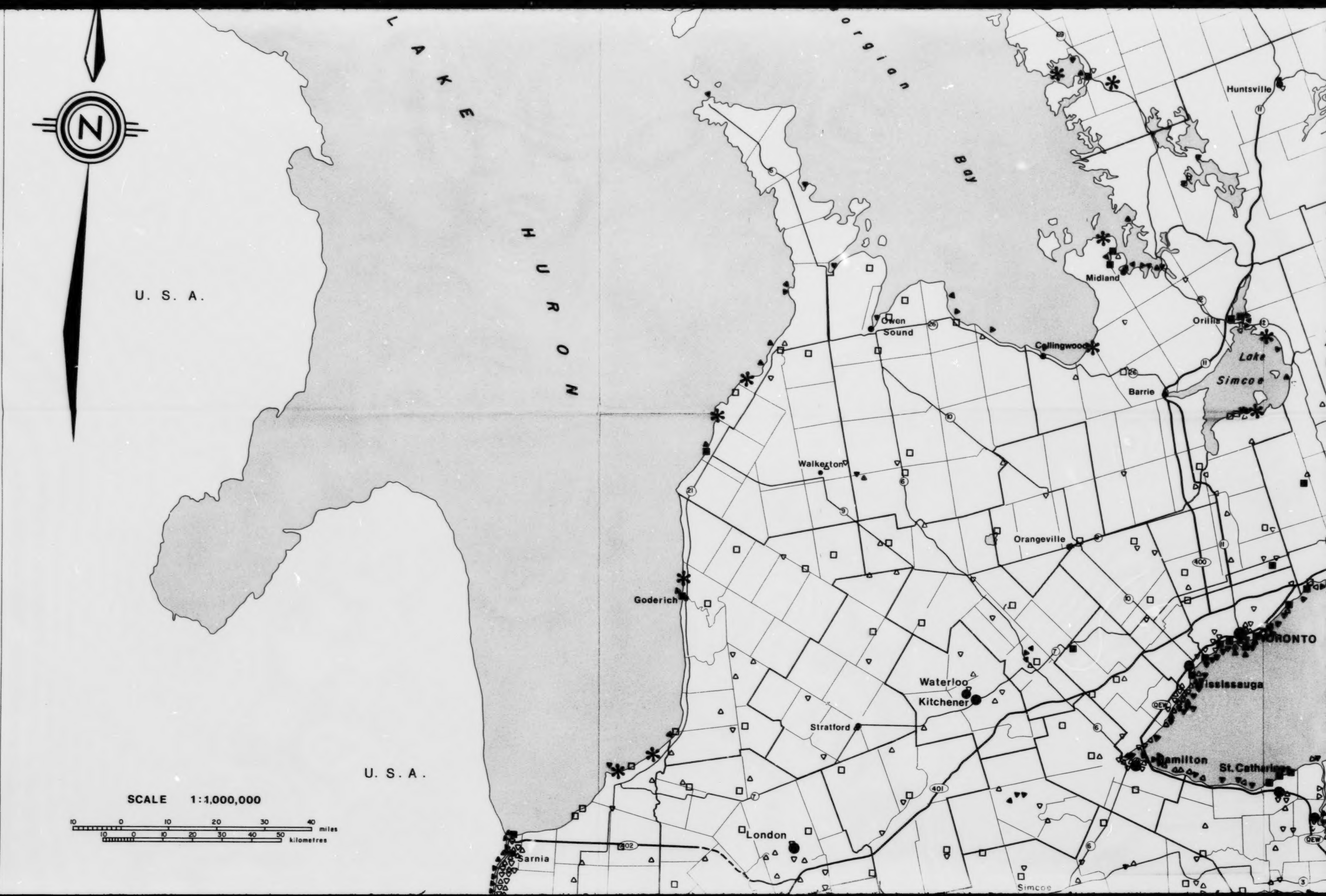
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Huntsville
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Lake Simcoe
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Owen Sound
Walkerton
Orangeville
Goderich
TORONTO
Mississauga
Waterloo
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Stratford
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London
Sarnia
Simcoe
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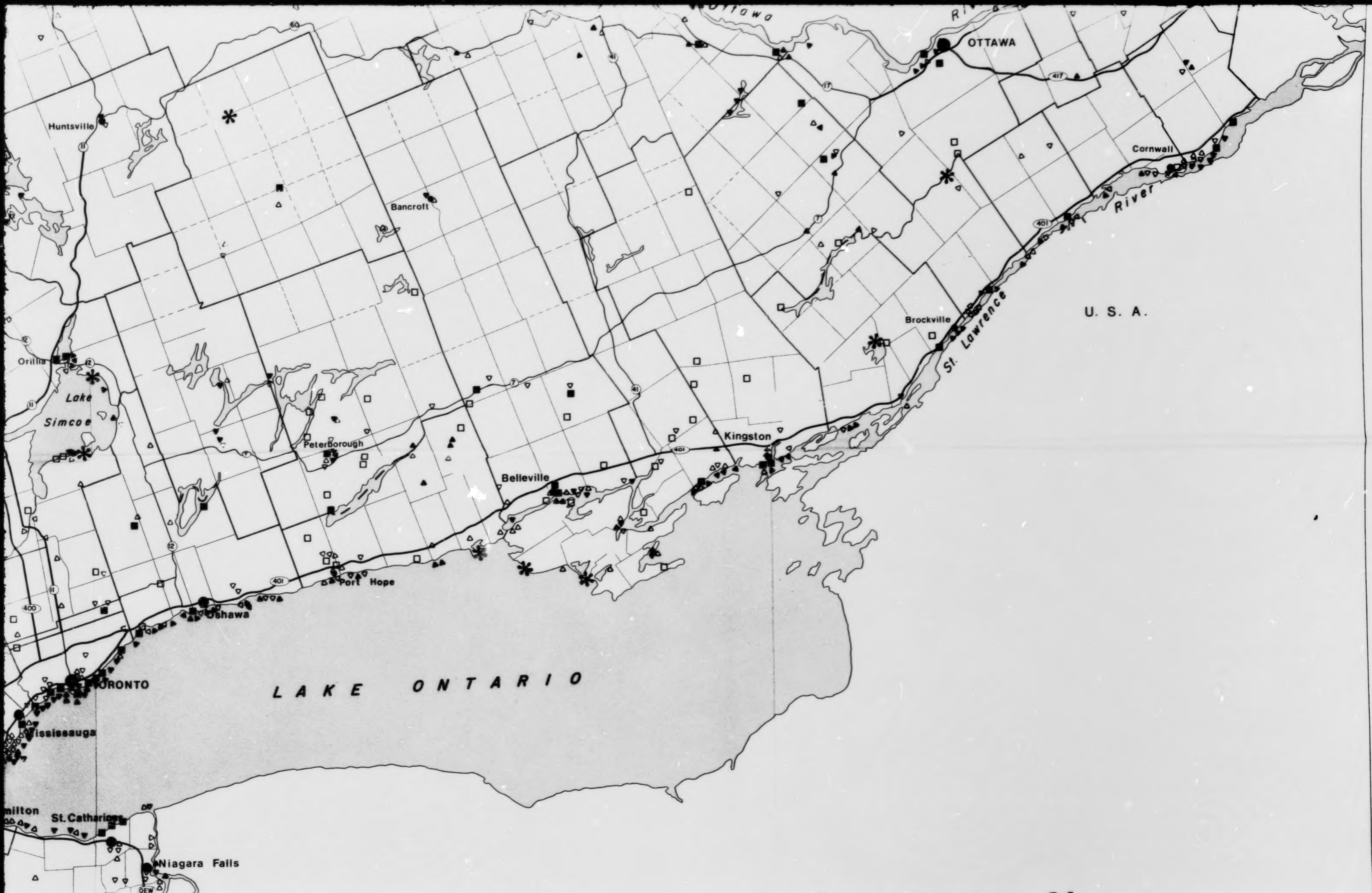
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Peterborough
Kingston
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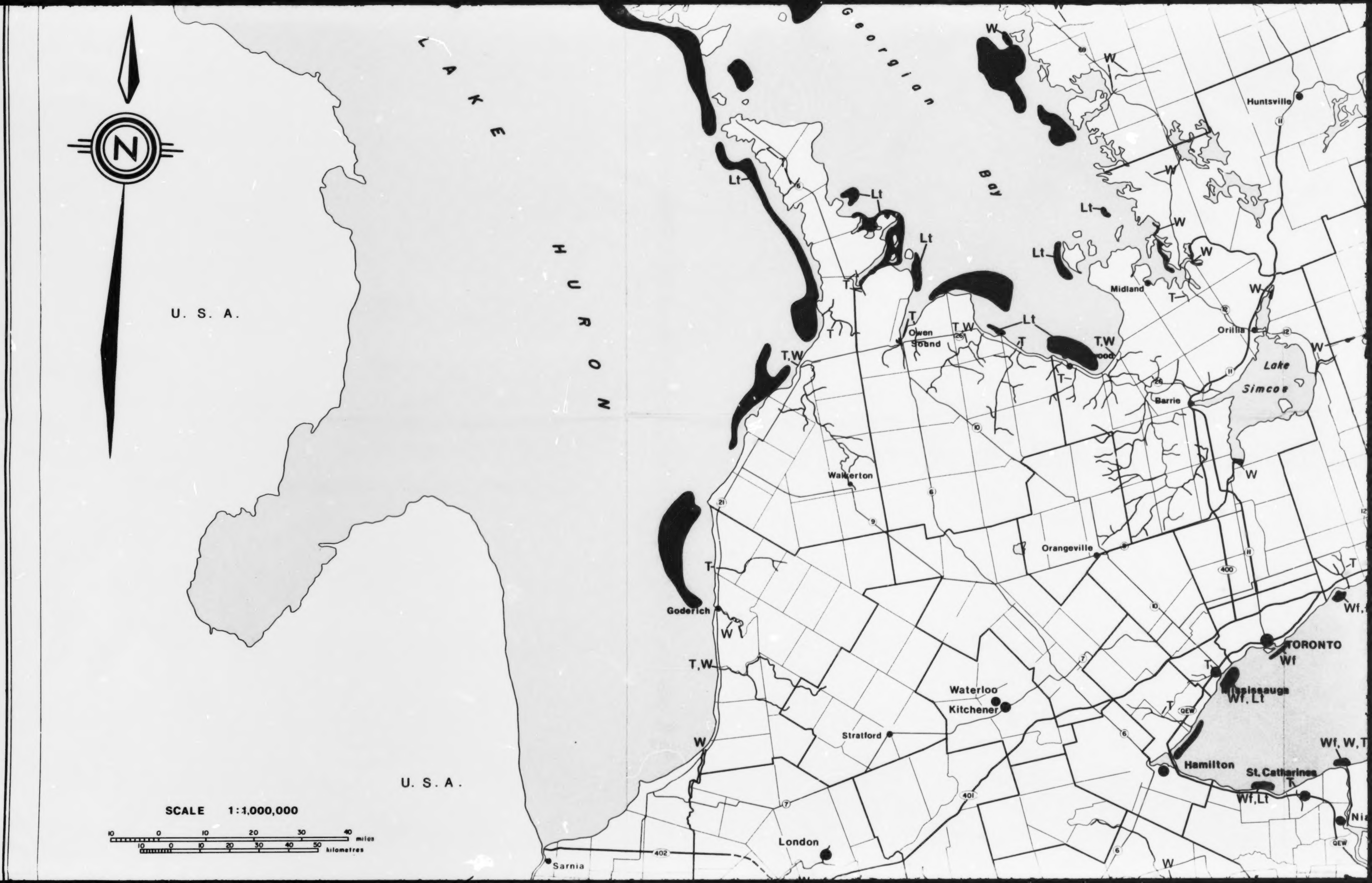
St. Catharines
Niagara Falls
QEW

Surface Water Uses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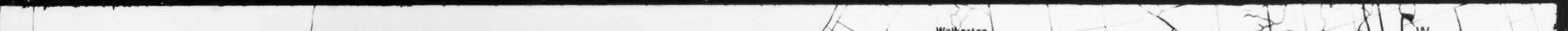
Walkerton
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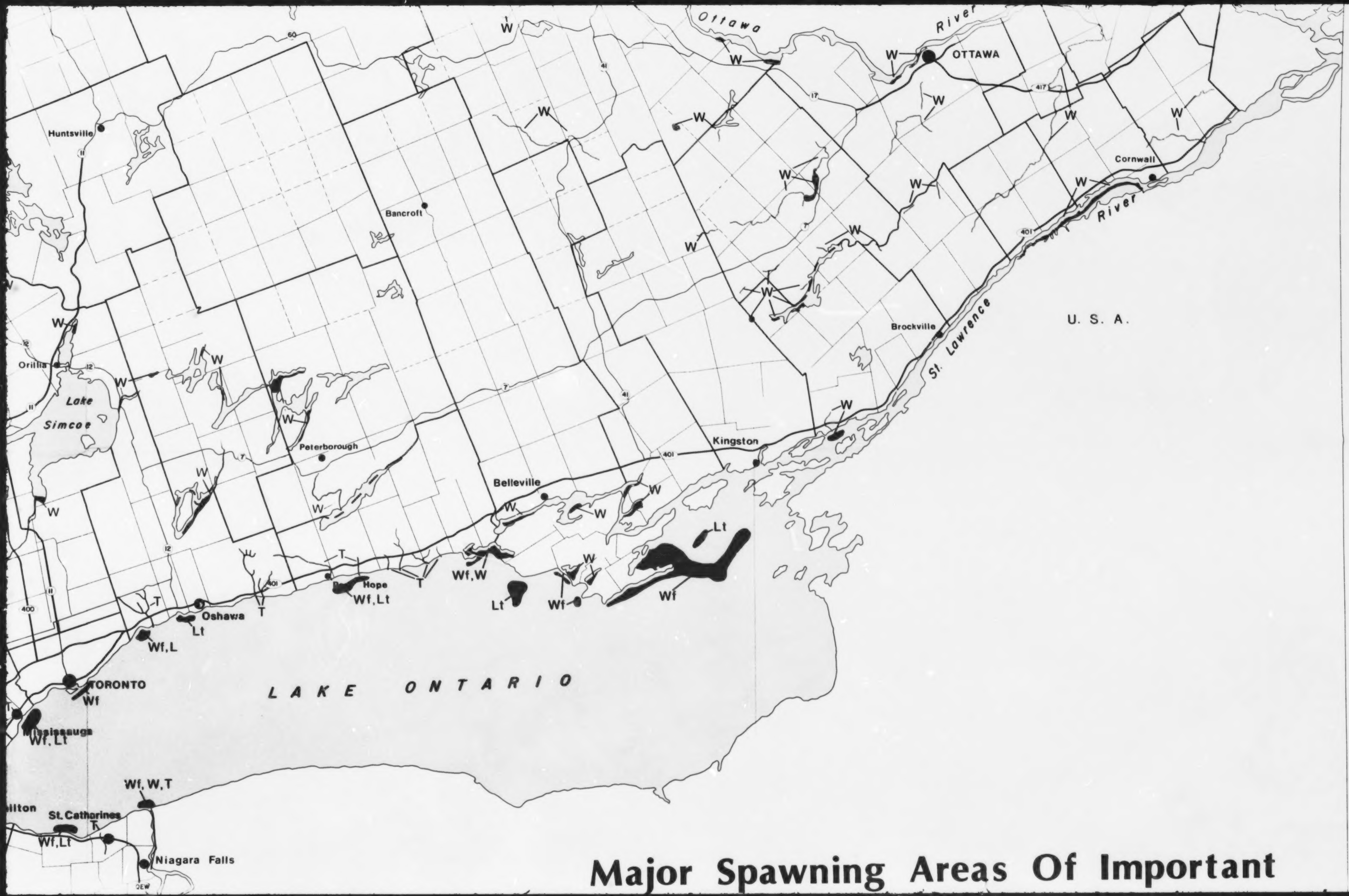
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Belleville
Port Hope
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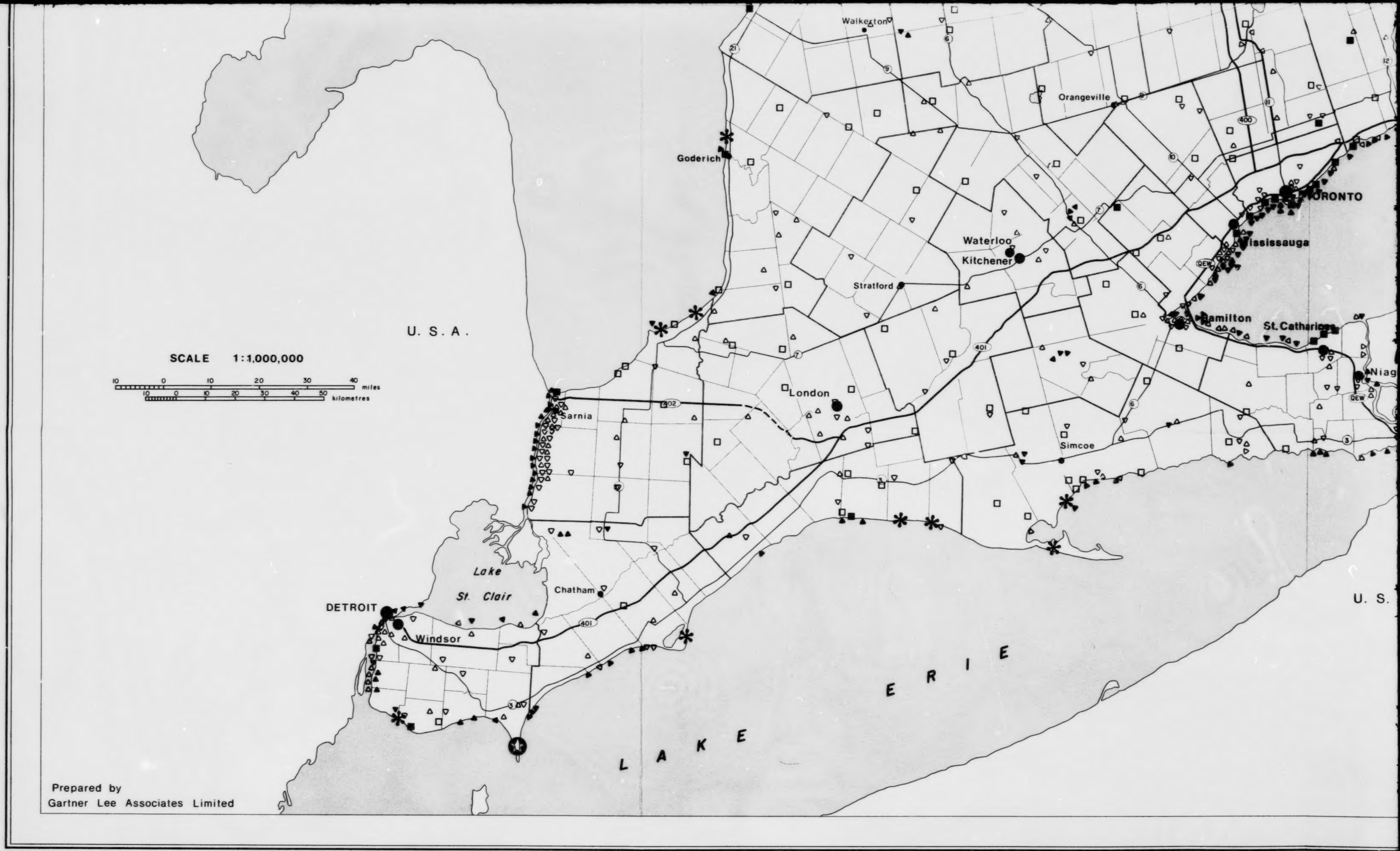
Major Spawning Areas Of Important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SCALE 1:1,000,000
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10 0 10 20 30 40 50 kilometres
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Sarnia
Simcoe
Lake St. Clair
Chatham
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Windsor
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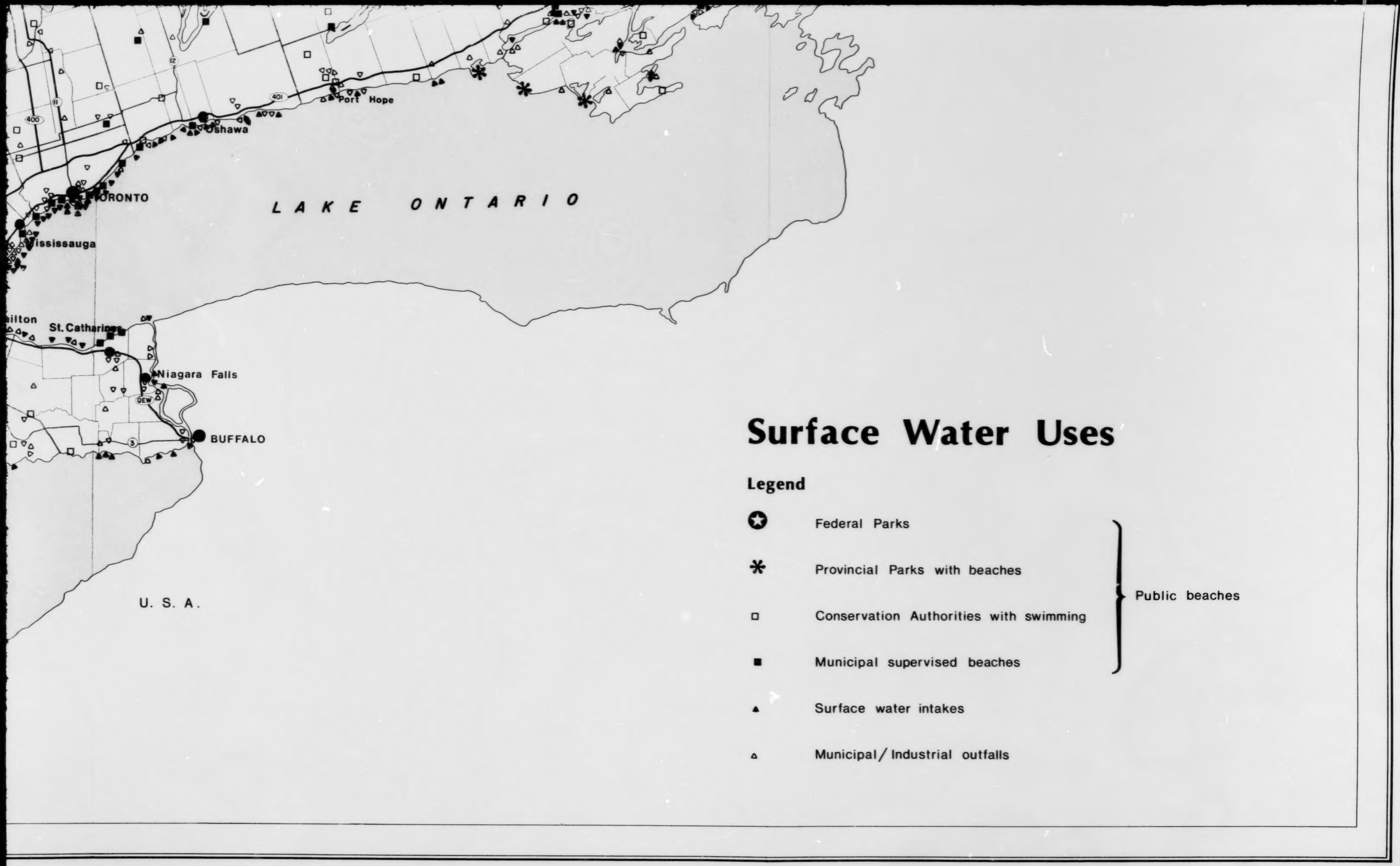
Prepared by
Gartner Lee Associates Limited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LAKE ONTARIO
Mississauga
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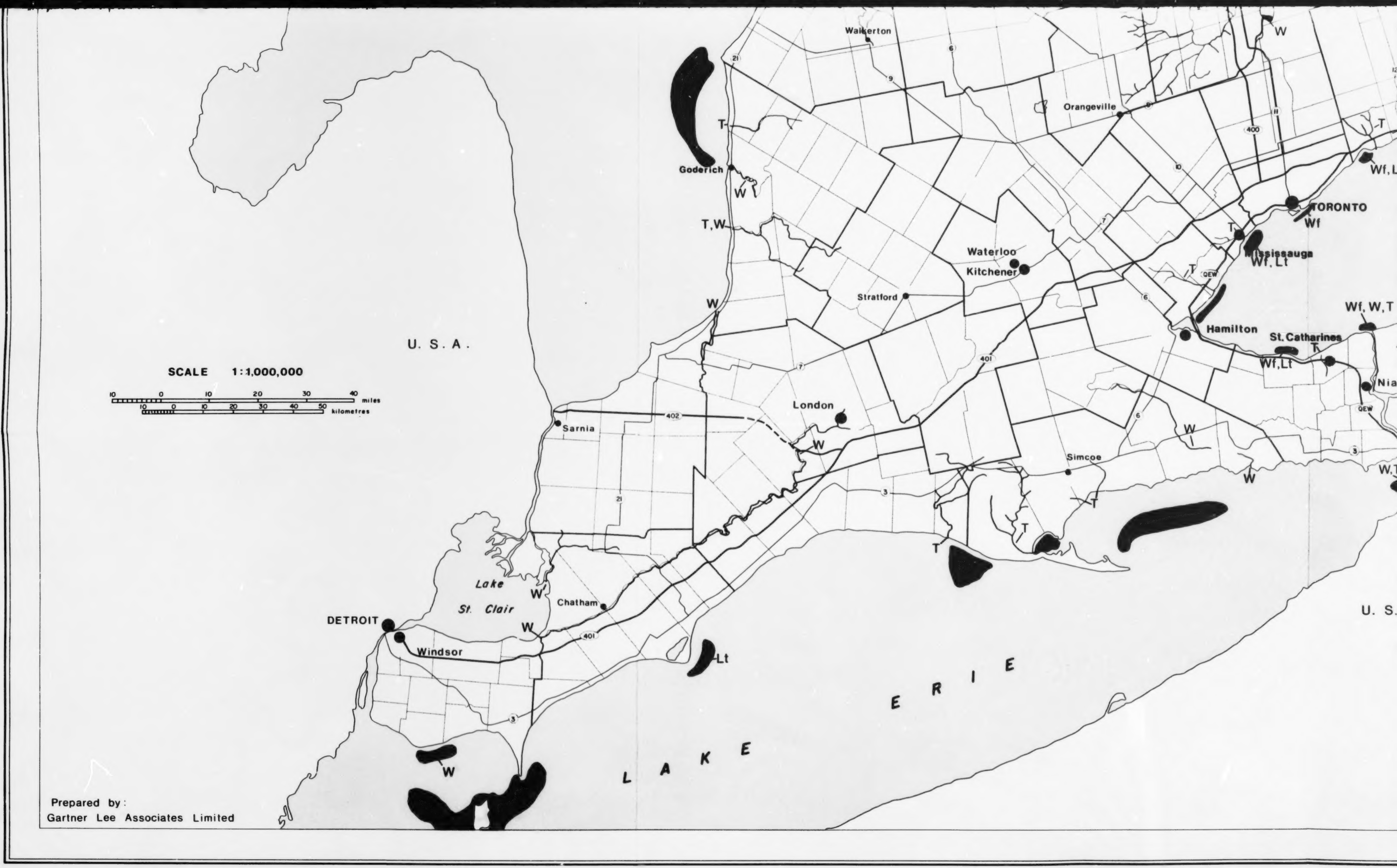
St. Catharines
Niagara Falls
QEW
3
BUFFALO
U. S. A.

Surface Water Uses

Legend

✪ Federal Parks
✱ Provincial Parks with beaches
□ Conservation Authorities with swimming
■ Municipal supervised beaches
Public beaches
▲ Surface water intakes
△ Municipal/Industrial outfalls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SCALE 1:1,000,000
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QEW
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Windsor
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LAKE ERIE
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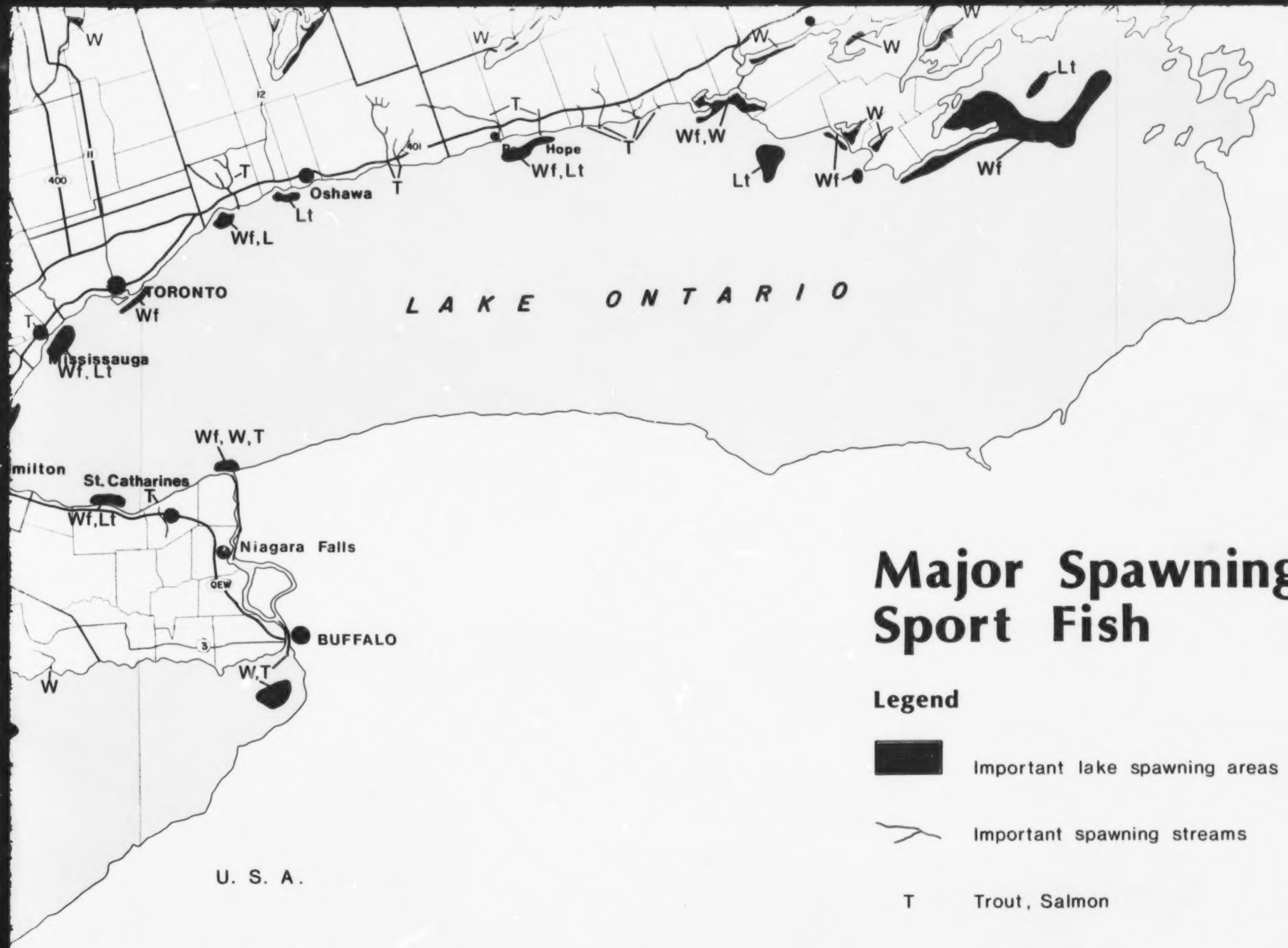
U. S.

Prepared by:
Gartner Lee Associates Limited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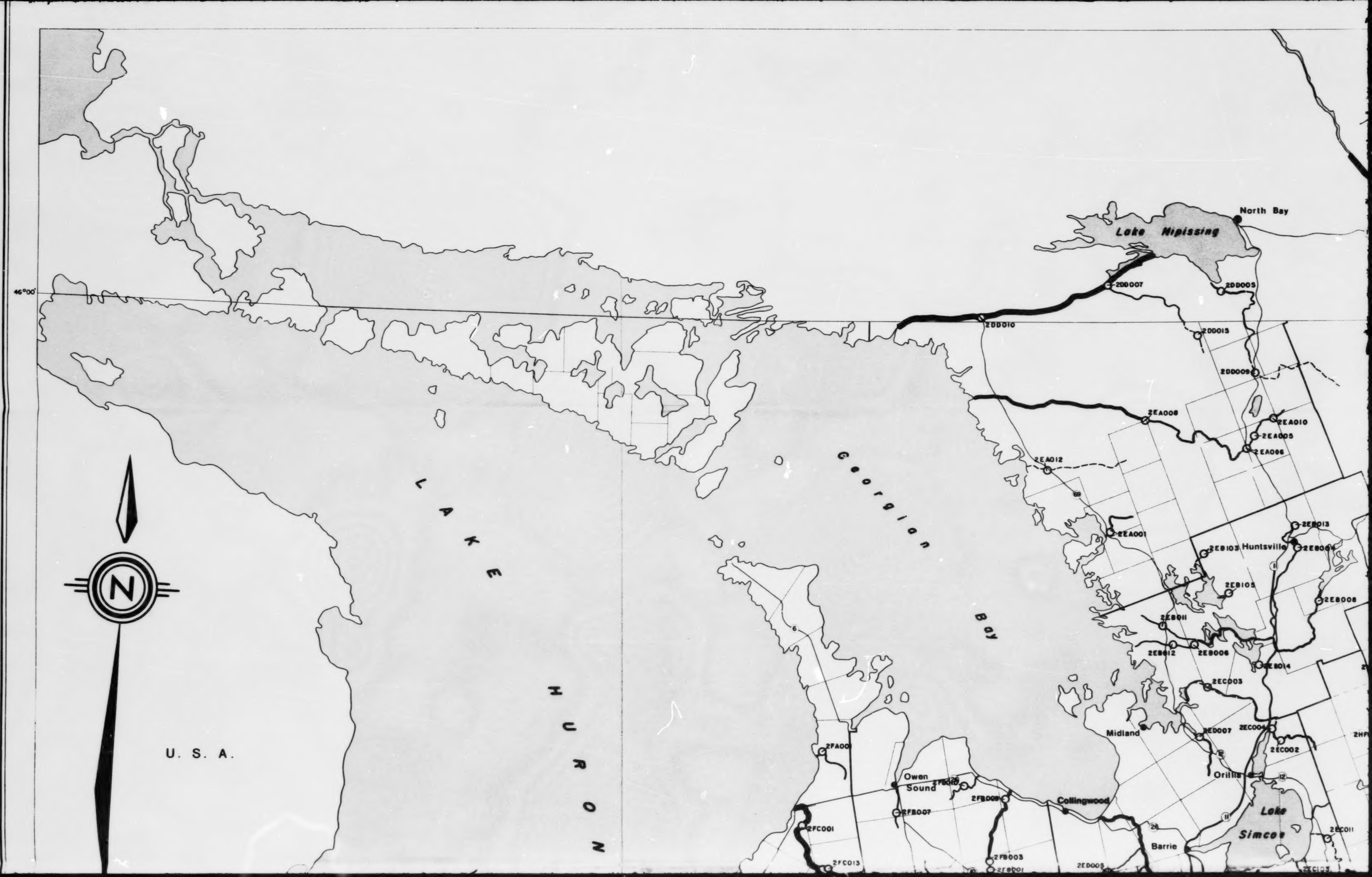
Major Spawning Areas Of Important Sport Fish

Legend

■	Important lake spawning areas
~	Important spawning streams
T	Trout, Salmon
W	Walleye
Wf	Whitefish
Lt	Lake Trout

NOTE: Minor inland fisheries excluded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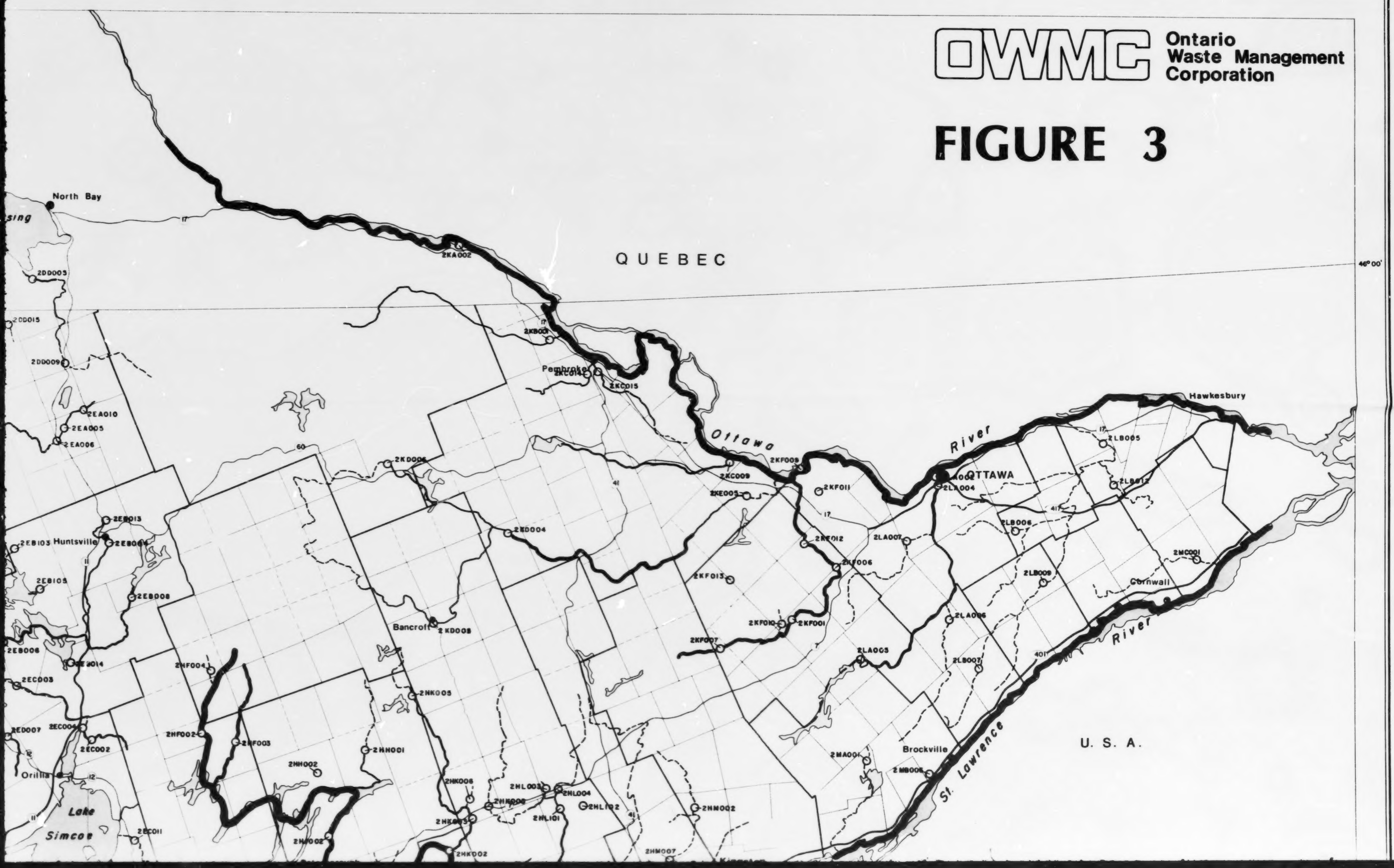
OWMC Ontario Waste Management Corporation

FIGURE 3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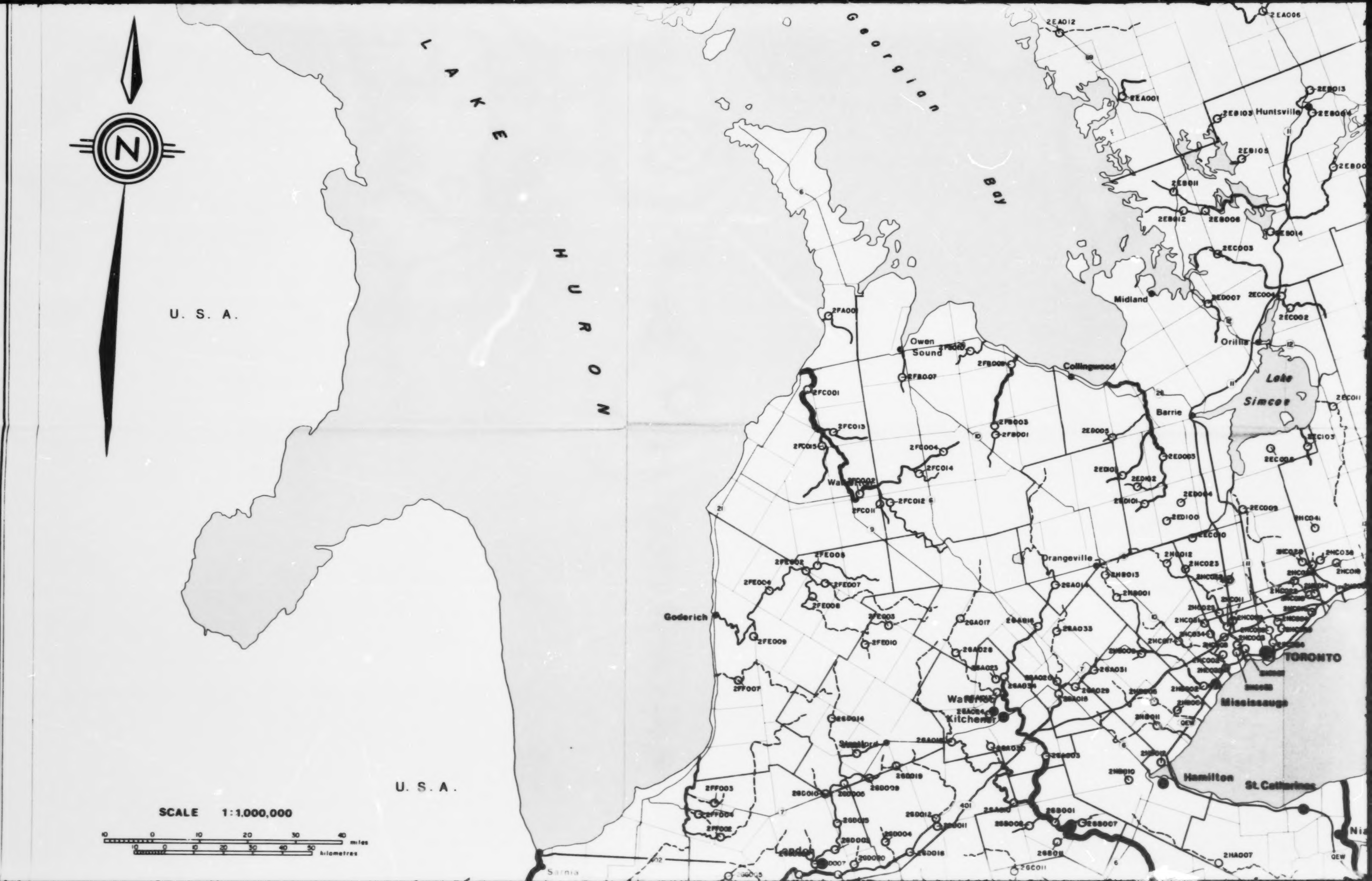
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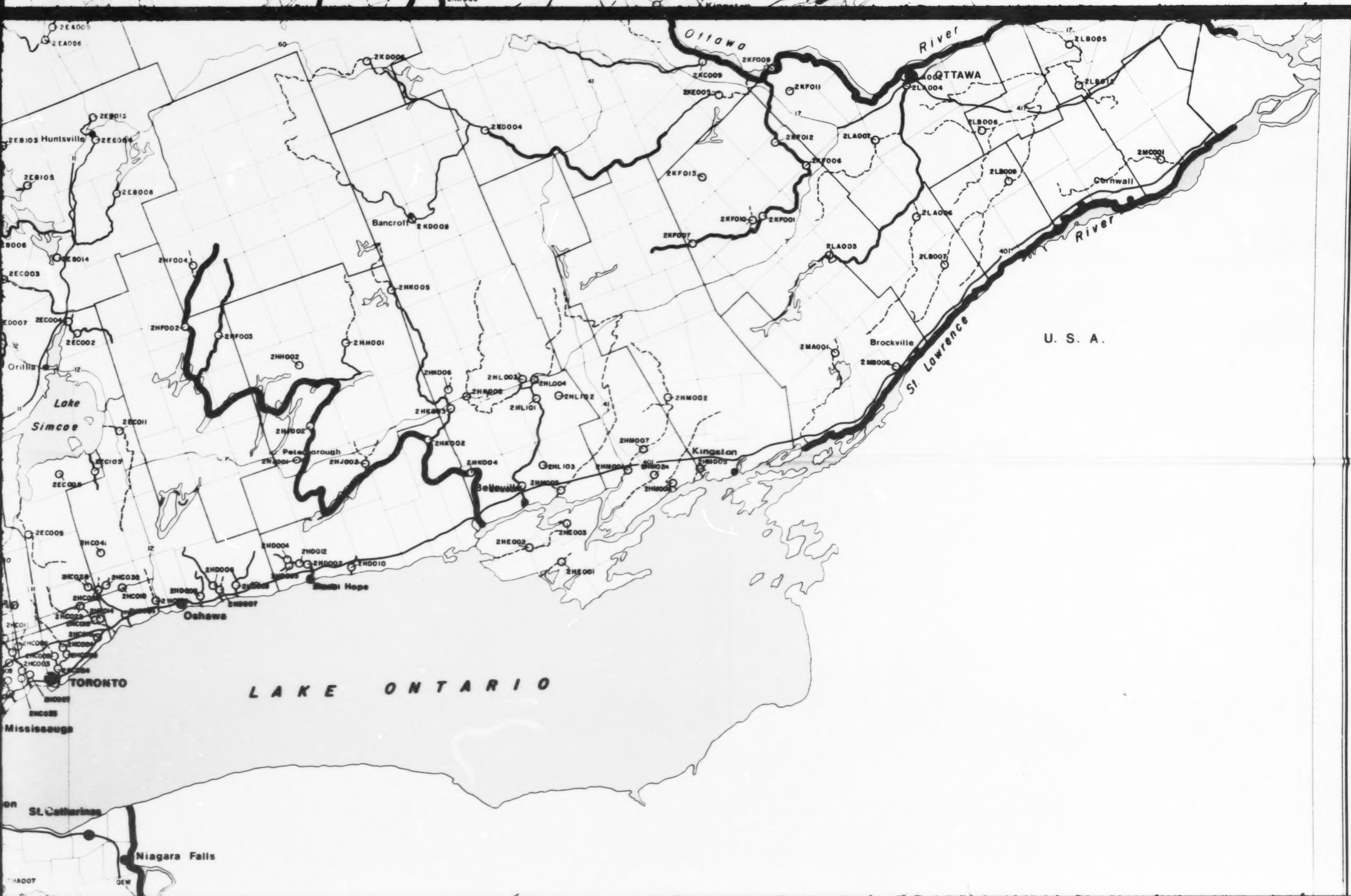
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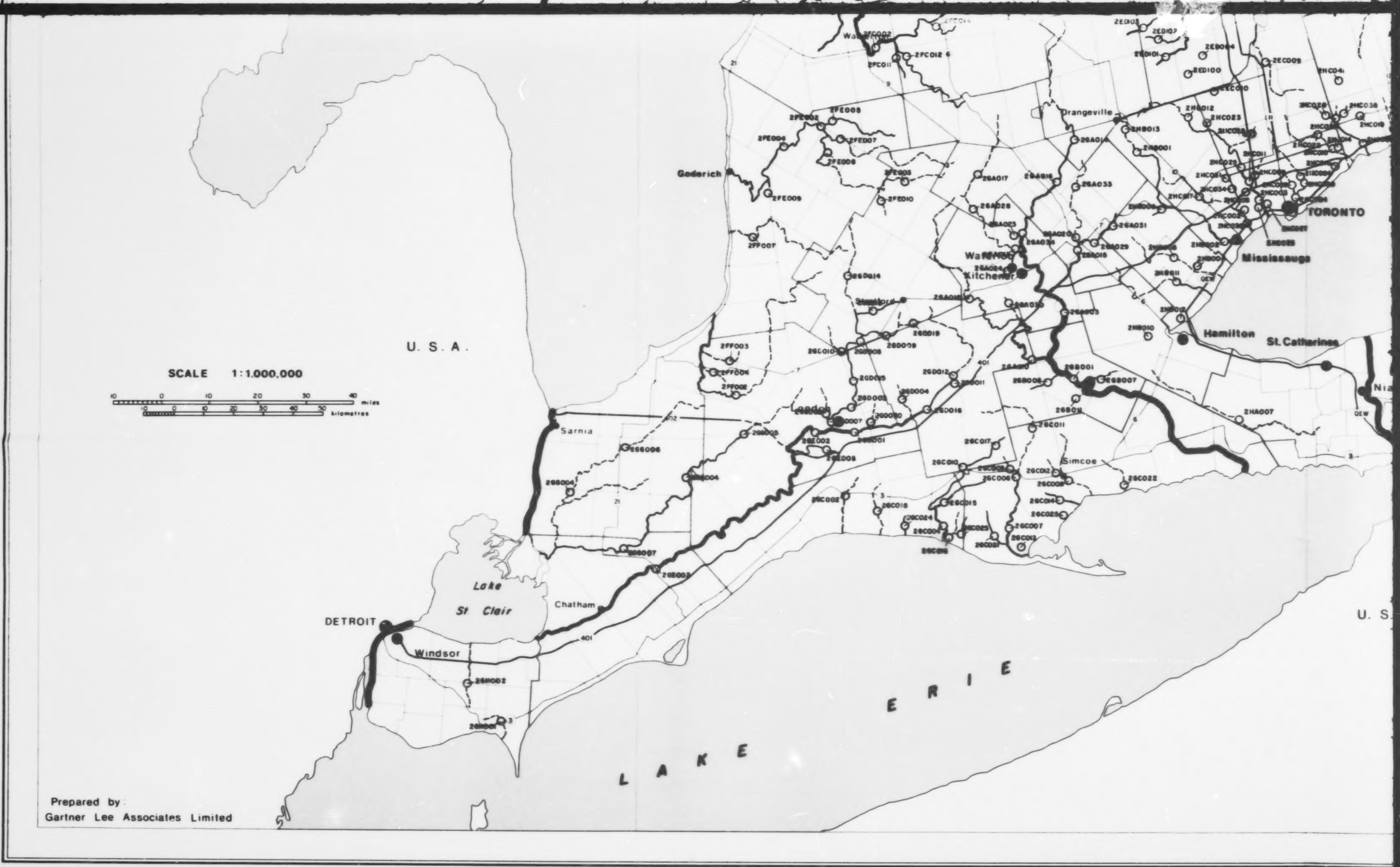
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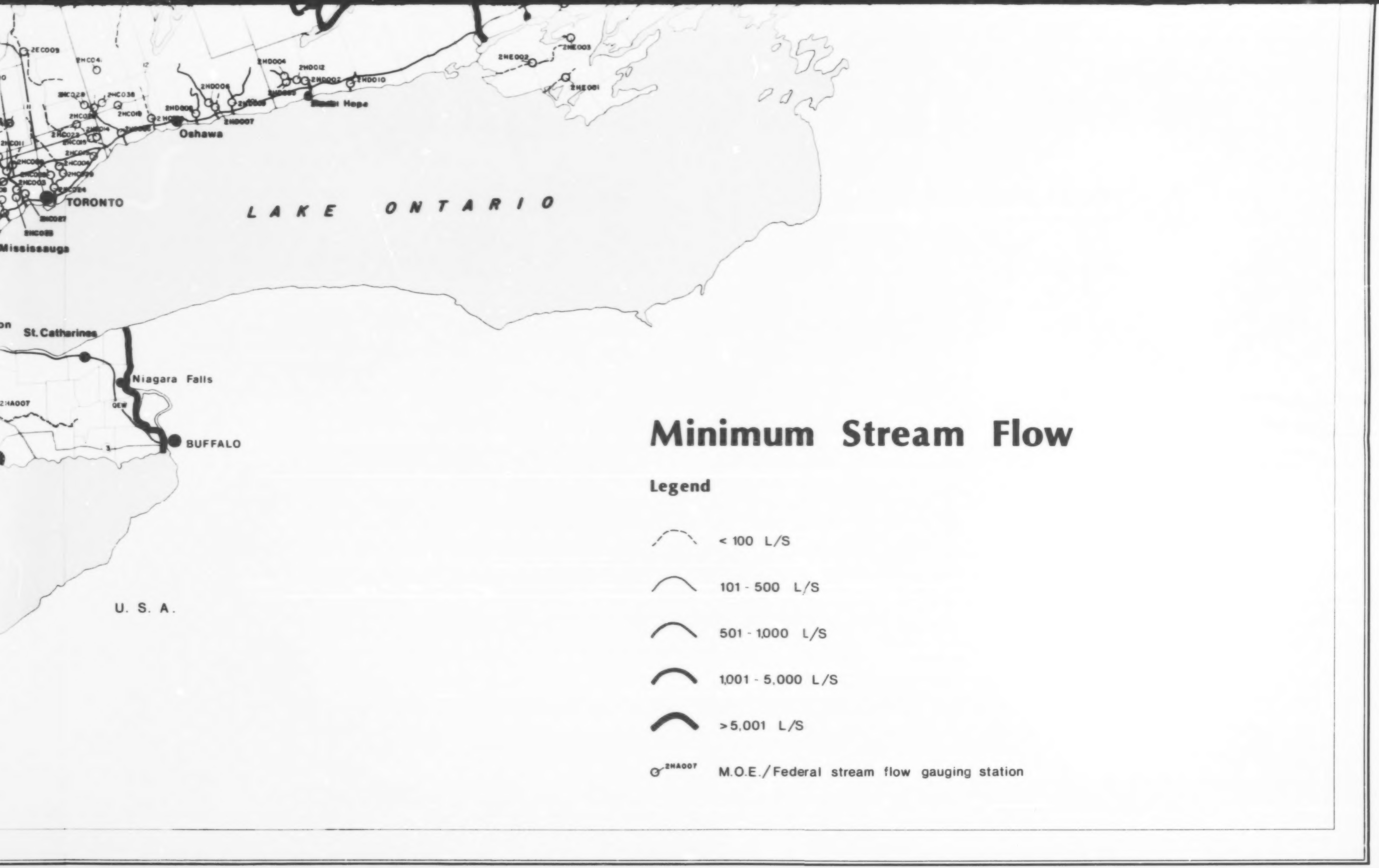

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Port Hope
Oshawa
TORONTO
Mississauga
LAKE ONTARIO
St. Catharines
Niagara Falls
QEW
2HA007
3
BUFFALO
U. S. A.

Minimum Stream Flow

Legend

< 100 L/S

101 - 500 L/S

501 - 1,000 L/S

1,001 - 5,000 L/S

>5,001 L/S

2HA007 M.O.E./Federal stream flow gauging station

Number/
Numéro

3

OWMC

FINAL REPORT

Ontario Waste Management Corporation

PRIMARY ENVIRONMENTAL INFORMATION
PART 3
ARCHAEOLOGICAL RESOURCES

Gartner Lee Associates Limited

Engineering Geologists, Hydrogeologists, Biologists, Environmental Consultants

Gartner Lee Associates Limited

Consulting
Engineering
Geologists and
Hydrogeologists

Toronto-Buttonville Airport ■ Markham, Ontario ■ L3P 3J9 ■ 416-477-8400
Telex - 06-986278

PRIMARY ENVIRONMENTAL INFORMATION
PART 3
ARCHAEOLOGICAL RESOURCES

PREPARED BY:

MUSEUM OF INDIAN ARCHAEOLOGY (LONDON)

FOR

GARTNER LEE ASSOCIATES LIMITED

PROJECT NO. 82-1005

SEPTEMBER, 1982.

Gartner Lee Associates Limited

Consulting
Engineering
Geologists and
Hydrogeologists

Toronto-Buttonville Airport ▪ Markham, Ontario ▪ L3P 3J9 ▪ 416-477-8400
Telex - 06-986278

September 3, 1982.

Mr. E.H. Schmidt, P.Eng.,
Project Director,
Ontario Waste Management Corporation,
60 Bloor Street West,
Suite 707,
Toronto, Ontario,
M4W 1A1.

Dear Mr. Schmidt:

Re: Final Report - Preliminary Environmental Information, Part 3 - Archaeological Resources - GLAL 82-1005

We respectfully submit the Final Report on archaeological resources as prepared by the Museum of Indian Archaeology, (London). The report provides a general overview of archaeological resources in Southern Ontario and documents trends indicated by known archaeological data which are useful in assessing archaeological site potential. Finally, the report places in perspective, how archaeology can affect the Facilities Development Process.

Both the Museum of Indian Archaeology and Gartner Lee Associates Limited are pleased to have been of service.

Yours very truly,

GARTNER LEE ASSOCIATES LIMITED

Grant Anderson

E.G. Anderson, P.Eng.,
Consulting Hydrogeologist.

DSO:jcm
Enclosures.

MUSEUM OF INDIAN ARCHAEOLOGY (LONDON)

An Affiliate of The University of Western Ontario

A Review of Archaeological Resources As They Affect the Facilities Development Process

Ontario Waste Management Corporation

Submitted to

Gartner Lee Associates Limited

Prepared by

Museum of Indian Archaeology (London)
September 1982

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Project Personnel

William D. Finlayson	Consulting Archaeologist
Robert J. Pearce	Project Archaeologist
Robert H. Pihl	Project Archaeologist
Robert G. Mayer	Graphics Co-ordinator

We would like to acknowledge the assistance of our support staff: Marilyn Tate - Word Processing, and Pat van Dyk - Administration.

Completion of this project also required the assistance of numerous people from the Archaeology and Heritage Planning Branch, Ministry of Citizenship and Culture, and we acknowledge their help:

Peter Carruthers	Archaeological Coordinator
William Fox	Regional Archaeologist, Southwestern Region
Roberta O'Brien	Regional Archaeologist, Southcentral Region
Allen Tyyska	Archaeological Research Supervisor

1.0 SUMMARY

1.1 Summary Statement

This study provides a general overview of archaeological factors which should be considered by the Ontario Waste Management Corporation in its Facilities Development Process.

The density distribution of archaeological sites by Borden Block acts as the primary data base to show where archaeological sensitive areas occur across southern Ontario. A description of the cultural chronology for the study region illustrates the nature of and trends in the known archaeological data. This is useful in assessing archaeological site potential.

This study then presents a detailed outline of how archaeology works within the Facilities Development Process. The examination approach proposed utilizes three sequential phases: background research, archaeological survey, and mitigation. The legal justification for this approach is also outlined.

1.2 Introduction

This study provides a general overview of archaeological resources in southern Ontario. It is designed to review those factors of an archaeological nature which should be considered by the Ontario Waste Management Corporation in its Facilities Development Process.

The report contains the following:

- an inventory of registered archaeological sites in southern Ontario by Borden Block;
- a discussion of the distribution of sites with reference to the history of archaeological investigation and an outline of the eleven-thousand year prehistoric occupation of Ontario;
- a review of several case studies and discussion of how archaeology can effect the Facilities Development Process;
- a review of the legal implications of the Ontario Heritage Act, the Environmental Assessment Act, and the Ministry of Citizenship and Culture's working policy on the discovery and handling of Native burials;
- conclusions and recommendations which derive from this study.

1.3 Inventory of Known Archaeological Sites

All archaeological sites discovered are registered with the Ministry of Culture and Citizenship by means of a Borden number. A Borden Block encompasses an area of 10 minutes latitude by 10 minutes longitude; each block is designated by a unique set of letters in the format: AgHh, AgHi, etc. The central office of the Archaeology and Heritage Planning Branch, Ministry of Citizenship and Culture, maintains a file of all registered sites. This file was consulted to obtain the data necessary for this report. A map of the study area (southern Ontario) at the scale of 1:670,000 was lined with Borden Blocks, and the numbers of registered sites within each Borden Block were coded onto the map in five classification groups (0 sites, 1 to 10 sites, 11 to 20 sites; 20 to 50 sites, and more than 50 sites).

A second map was compiled to illustrate 25 areas and two transects through Ontario which have high archaeological site densities. If the Facilities Development Process were to select any of these areas for a waste disposal facility, there is an extremely high probability that one or more known archaeological sites would be threatened; there is also a high probability that an intensive archaeological survey for a proposed waste disposal facility within any of these areas would encounter significant archaeological resources.

1.4 Archaeological Investigations in Southern Ontario: A History and Cultural Chronology

This section deals with two topics:

a) a history of archaeological investigations in southern Ontario; and
b) a discussion of the prehistoric cultural framework in southern Ontario.

Although museum-related archaeological investigations, including excavation, began in earnest in southern Ontario around the turn of the century and increased in the 1940's and 1950's when university-related research began, the real florescence occured only in the 1970's. This resulted from two factors: a program initiated by the Ministry of Natural Resources to inventory the archaeological resources within its Provincial Park holdings for heritage planning purposes; and the passage of The Ontario Heritage Act, 1974 and The Environmental Assessment Act, 1975 which stimulated an increase in archaeological consulting activity.

The prehistory of southern Ontario has been divided into four successive periods:

- Palaeo Indian (9000-5000 B.C.): this period characterizes the original occupants of southern Ontario who were adapted to glacial conditions and were essentially nomadic hunters pursuing migrating caribou herds;

- Archaic (5000-1000 B.C.): this period charts the transition of cultures from glacial to essentially modern conditions. These people were hunters, gatherers and fishers who were adapted to river drainages and had a semi-sedentary lifestyle;

- Woodland (1000 B.C.-A.D. 1650): this period sees enormous changes occur in artifact styles, subsistence and settlement patterns, and social organization. Where lithics were characteristic of the earlier periods, ceramics now predominated. Horticulture was introduced and village patterning and internecine warfare between rival groups evolved. Contact with European traders, missionaries, and settlers set in motion trends that would eventually lead to the dispersal of the aboriginal groups of southern Ontario around A.D. 1650;

- Historic (A.D. 1650-1900): this period involves the re-occupation of parts of southern Ontario by Algonkian-speaking groups to take advantage of the rich fur-trading opportunities arising along the north Lake Ontario shoreline. This period also encompasses the establishment of Native reservations.

Trends in subsistence, settlement, social and mortuary patterning are discussed in this section as an aid to understanding the distribution of archeological resources in southern Ontario.

1.5 Archaeology and the Facilities Development Process

This section is composed of two parts:

a) a discussion and comparison of two types of archaeological case studies; and
b) a detailed presentation of a three-phase approach to conduct archaeological examinations for the Facilities Development Process.

The case studies represent two types of archaeological inventory: one passive and one active. The passive type deals with an inventory of known (registered) sites within a generalized study region and is designed to be used for long-term planning so that high density zones can be singled out and either avoided or properly assessed. The active type deals with an intensive field survey of a specific project area to discover the total range of archaeological resources. Although useful for long-term planning, this survey is usually initiated when more immediate impact is scheduled. Taken together, the two types of case studies suggest an assessment approach which is formalized below.

The approach which is favoured here is divided into three phases: background research, archaeological survey, and mitigation.

The background research (Phase I) involves the following:

- review of existing archaeological resources;
- estimation of archaeological site potential within the generalized study region (including an assessment of areas with no previously known sites);
- recommendations concerning areas within the study region which should be avoided due to high archaeological potential.

Archaeological survey (Phase II) involves the detailed examination of a project area which has been selected. The survey strategy depends on the type of vegetation within the project area. Closed vegetation such as pasture or woodlot requires a time-consuming and labour-intensive (and therefore costly) test-pitting strategy. Open vegetation such as cropland planted in corn or beans or ploughed fields can be examined cost-effectively by transect survey. A multi-staged survey programme conducted over several field seasons is recommended; this will optimize the availability of open vegetation for surveying and will ensure as accurate an assessment as possible. The survey will attempt to:

- locate archaeological resources (or re-verify the locations of existing resources) within the project area;
- ascertain areal dimensions and cultural affiliations of the sites;
- make recommendations as to which archaeological resources should be preserved, mitigated and/or sacrificed.

Finally, for those sites that require mitigation (Phase III), a two-step procedure is proposed. First, it is recommended that sampling excavations be performed to test the presence of sub-surface deposits. Once they have been confirmed and proved productive, then complete excavation can commence. Both excavations deal with disturbed and undisturbed deposits and attempt to:

- secure artifact samples and lifeway information (such as food remains);
- record and excavate all examples of aboriginal settlement pattern such as structures, middens, etc.
- analyze all information and produce a report detailing the results of the excavation.

1.6 Implications of the Ontario Heritage Act, The Environmental Assessment Act, and the Discovery of Native Burials

This section outlines various legal implications, including:

a) the "stop work" order and licencing requirements of the Ontario Heritage Act;
b) the requirement that archaeological assessments be conducted as part of environmental assessments under the Environmental Assessment Act;
c) the Ministry of Citizenship and Culture's working policy regarding the discovery, excavation and analysis of Native burials.

The Ontario Heritage Act, 1975, established the Ontario Heritage Foundation which has, as one of its mandates, "to preserve, maintain, reconstruct, restore and manage property of historical, architectural, archaeological, recreational, aesthetic and scenic interest".

All types of archaeological investigation (survey, fieldwork, excavation) require a licence, obtained through application to the Ontario Heritage Foundation.

The Act contains a "stop work" clause which empowers the Minister of Citizenship and Culture to shut down construction projects for a period of up to 180 days, to enable qualified archaeologists to salvage archaeological material from a property of archaeological or historical significance that is being threatened by that construction.

The Environmental Assessment Act, 1975 requires an environmental assessment to be completed prior to initiation of certain construction projects. The Act includes in its description of environment "any building, structure, machine or other device or thing made by man". All archaeological and historical sites are thus covered under this Act. Specific guidelines as to the nature, content and recommendations of the man-made component of environmental assessments are outlined in detail in this study.

The Ministry of Citizenship and Culture has a working policy regarding the discovery, excavation and analysis of Native burials. The procedures recommended in this policy can be summarized as follows:

- an archaeological licence issued by the Ministry of Citizenship and Culture does not permit the excavation of human burials;
- if human burials are discovered, the Regional Archaeologist of the Ministry of Citizenship and Culture must be contacted;
- the Regional Archaeologist will contact the local coroner and Cemeteries Branch;
- if the burial is Native, the Regional Archaeologist will contact the local Indian band chief;
- if the band chief agrees to allow excavation, the Regional Archaeologist must obtain a certificate to exhume and transport human remains from the Regional Medical Officer

of Health;
- the Regional Archaeologist will exhume and transport the remains, and arrange for their analysis;
- if the burial is not jeopardized by construction, it will not be exhumed; the burial will be registered as an official cemetery and come under the jurisdiction of the local municipality.

1.7 Conclusions

Based on the discussions presented in the previous sections, three working conclusions can be presented:

- there are only three broad areas of southern Ontario which, based on present knowledge, have no registered sites:

    1) the area west of the Niagara Escarpment, south of Owen Sound, east of Kincardine and north of Listowel;

    2) the area west, east and south of Algonquin Park extending westward to Parry Sound, southward to Lakefield and eastward to but not including the Ottawa River; and

    3) the area southeast of Ottawa, southward to Winchester and eastward to but not including the Ottawa River.

- given the ubiquitous nature of archaeological sites, intensive survey should be conducted in project areas selected for a waste disposal facility before construction begins. This measure is a requirement of the Environmental Assessment Act.

- finally, should an archaeological site be contained within a proposed facility location, there are a set of procedures available to deal with it on an avoidance or mitigation basis.

2.0 INTRODUCTION

This study was undertaken to provide a general overview of the archaeological resources of southern Ontario to assist the Ontario Waste Management Corporation in its Facilities Development Process. The study is designed to review those factors of an archaeological nature which should be considered by the Ontario Waste Management Corporation.

This report deals with four interrelated aspects of southern Ontario's archaeological resources:

> 3.0: an inventory of known archaeological sites in southern Ontario by Borden Block;
>
> 4.0: a discussion of the distribution of sites with reference to the history of archaeological investigation and an outline of the eleven-thousand year culture history of southern Ontario;
>
> 5.0: a discussion of how archaeology can effect the Facilities Development Process by means of a brief review of several case studies in which archaeology has been an important factor in the development of the required facilities; and
>
> 6.0: a review of the implications of the Ontario Heritage Act, the Environmental Assessment Act, and the Ministry of Citizenship and Culture's working policy regarding discovery and handling of Native burials for the Facilities Development Process.

Section 7.0 of this report contains conclusions based on the information in Sections 3.0 to 6.0. Data relevant to the discussions in Sections 3.0 to 7.0 are contained in Sections 9.0 to 11.0 (Appendices A - C).

3.0: INVENTORY OF KNOWN ARCHAEOLOGICAL SITES IN SOUTHERN ONTARIO

3.1 Introduction

All archaeological sites, including prehistoric and historic aboriginal camps, villages, workshops, burials and quarries, early historic European sites (i.e. cabins, mills, towns, etc.) and shipwrecks, which are discovered in Canada are registered by the Borden scheme. This system was devised by Dr. Charles Borden (1952) and was adopted by the Federal government (i.e. National Museum of Man, National Museums of Canada) and the appropriate provincial agencies (i.e. Ontario Ministry of Citizenship and Culture). The Borden system divides the country into a series of blocks based on latitude and longitude. A "Major Unit" is two degrees longitude east to west by two degrees latitude south to north and is designated by capital letters such as AH. Each Major Unit block is then subdivided into 288 "Basic Units", each 10 minutes by 10 minutes. The Basic Unit, which measures approximately 7 miles east to west by 11.5 miles south to north, is designated by uncapitalized letters. Thus each Borden block with an area of about 80 square miles is identified by a unique set of four letters, such as AgHh.

Archaeological data in Ontario is coordinated through the central office of the Archaeology and Heritage Planning Branch, Ministry of Citizenship and Culture (formerly the Historical Planning and Research Branch, Ministry of Culture and Recreation). They maintain a record of all sites registered by Borden Block. Each time a new site is discovered, it is assigned the next consecutive number of the Borden Block in which it is located (i.e. the tenth site registered in block AgHh is referred to as AgHh-10).

The data compiled for this report was obtained by consulting the above-mentioned central files. The data is up-to-date as of May 26, 1982 (i.e. sites registered after that date are not included in this study).

The data obtained is summarized in two ways in this report. First, Appendix A (Section 9.0) contains an alphabetical listing of all Borden Blocks in southern Ontario (south of the 46th parallel), and the total number of sites registered for each of those locks. Second, a map at the scale of 1:670,000 is included showing the density of sites per Borden Block (see Map 1).

3.2 Discussion

The density map proved useful in generating two major conclusions:

1. Certain areas have a high archaeological site density; and
2. Certain areas of southern Ontario have a zero or low archaeological site density.

Concerning the first conclusion, the 1:670,000 map shows at least 25 areas of high archaeological site density. These 25 areas are shown more clearly on Map 2, and are briefly summarized in Appendix B (Section 10.0). The 25 areas exhibit high density for two reasons. First, these are actual areas of concentrated aboriginal settlement, and second, they are areas that have been intensively and systematically surveyed by archaeologists. These form the basis for the discussion of southern Ontario's cultural history in Section 4.0. A number of these areas are chosen as case studies and are further described in Section 5.0 and Appendix C (Section 11.0).

The areas of zero archaeological density reflect, to a certain degree, the absence of known archaeological sites. This is further elaborated upon in the discussions in Section 4.0 and the cultural history maps in that section. However we must caution that, in general, the areas of zero density have not been the focus of archaeological research to date; they may contain sites which remain to be discovered and/or registered.

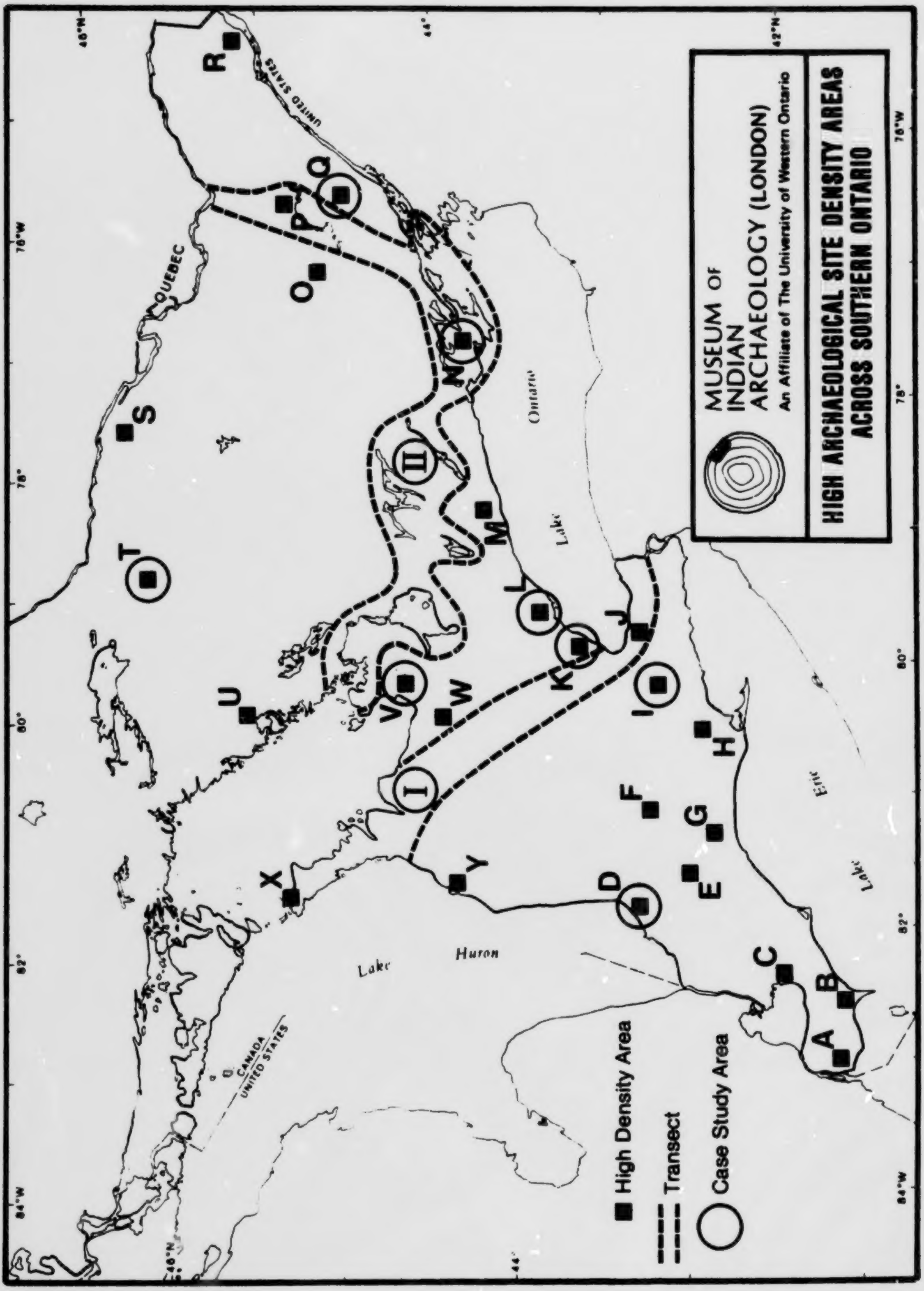
3.3 Limitations of the Data

There are certain inherent limitations in the data used in this report which require explanation. These are as follows:

1. The data are accurate only in so far as they are currently on file at the Archaeology and Heritage Planning Branch, Ministry of Citizenship and Culture. We cannot be responsible for any errors which may exist in the central file as of May 26, 1982;

2. The data used in this study were current as of May 26, 1982. Given the time restraints of this study we have no way of noting all of the unregistered sites throughout the study area, even though some areas are known to have large numbers of unregistered sites;

3. The density distribution does not make any distinction between prehistoric and historic (i.e. European) sites. As indicated by the case studies in Section 5.0, several Bordenized sites are European (e.g. farmsteads). The density distribution also does not distinguish land-based archaeological sites from underwater shipwrecks. It does not distinguish sites within a Borden Block by cultural period (e.g. Archaic versus Woodland); nor does it distinguish types of sites (e.g. findspot versus village, campsite versus quarry, etc.).


HIGH ARCHAEOLOGICAL SITE DENSITY AREAS ACROSS SOUTHERN ONTARIO
MUSEUM OF INDIAN ARCHAEOLOGY (LONDON)
An Affiliate of The University of Western Ontario
■ High Density Area
Transect
○ Case Study Area
Lake Huron
Lake Ontario
Lake Erie
QUEBEC
UNITED STATES
CANADA
UNITED STATES
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
S
T
U
V
W
X
Y
I
II
46°N
44°
42°N
84°W
82°
80°
78°
76°W

Map 2

4.0: ARCHAEOLOGICAL INVESTIGATIONS IN SOUTHERN ONTARIO: A HISTORY AND CULTURAL CHRONOLOGY

This section will first present a brief history of archaeological work, and then provide a generalized culture chronology for the southern Ontario study area.

4.1 History of Archaeological Work in Southern Ontario

Archaeological work, in one form or another, has been undertaken in southern Ontario for nearly a hundred years. The start of non-professional work (under the guise of pot-hunting or amateur research) is difficult to pin-point since it was often covered only as a personal interest story in the newspaper, but it can be estimated to be around the mid-1800's. It continues today under the guidance of the Ontario Heritage Act (see Section 6.0). Professional work can be divided into three stages: museum-related research, university-related research, and heritage planning and conservation studies.

Museum-related archaeology had its beginnings in the mid 1890's when David Boyle and his associates conducted surveys and excavations in many areas of southern Ontario on behalf of the Provincial Museum (now the Royal Ontario Museum). This work was regularly reported in the Annual Archaeological Reports, Ontario between the 1890's and 1910's. Archaeologists from the Victoria Museum (now the National Museum of Man, National Museums of Canada), in particular William J. Wintemberg, also excavated numerous sites throughout southern Ontario in the 1920's-1940's. This work was reported in both American and Canadian professional journals and museum publications. Wilfrid Jury undertook numerous archaeological projects in southwestern Ontario and Georgian Bay for the Museum of Indian Archaeology and Pioneer Life, London. This work was usually published in the Museum's Bulletin series.

University-related archaeology began in the 1940's when Norman Emerson joined the newly formed Department of Anthropology at the University of Toronto. His fieldwork centred on the development of Huron culture in the area around Toronto, but he undertook other projects on the Ottawa and St. Lawrence Rivers and near Fort Erie, to mention a few areas. The real boom in university-related research occured in the late 1960's and 1970's when Anthropology departments with archaeologists and graduate programmes were formed in Peterborough, Hamilton, Kitchener-Waterloo, London and Windsor. Research projects were formalized and data collection began in earnest (see Section 10.0). Much of this research received major funding from the Canada Council (now Social Sciences and Humanities Research Council of Canada) and, after 1975, from the Ontario Heritage Foundation.

Finally and starting around 1970, the Ministry of Natural Resources began a concerted effort to assess the archaeological resources within its park holdings. This work, initiated by the Historic Sites Branch, was later transferred to the Historical Planning and Research Branch, Ministry of Culture and Recreation (HPRP-MCR) when the latter was created by the

Ontario Heritage Act. As of 1982 it is now known as the Archaeology and Heritage Planning Branch, Ministry of Citizenship and Culture (AHPB-MCC). Many of the Case Studies described in Section 11.0 (#1,3,5,6,7) resulted from these assessments. In addition, archaeologists from this branch (HPRB-MCR) conducted large scale archaeological inventory projects for housing developments (Case Study #2) and for several long term planning studies (Case Studies 8-10). Although research is still one of their functions, the primary mandate of the Archaeology and Heritage Planning Branch, Ministry of Citizenship and Culture is heritage planning and archaeological/historical conservation.

As a result of the Ontario Heritage Act, 1974 and the Environmental Assessment Act, 1975, there has been an increased involvement by non-governmental archaeologists in assessing the archaeological potential of areas to be developed by highways, pipelines, housing developments, industrial/commercial facilities, etc. Since this work is usually done on a contract basis, archaeological consulting firms have sprung up around the Province ready to compete for the available assessments. Follow-up mitigative work on impacted archaeological resources is also undertaken by these firms (Case Study #4).

Although this section has not done justice to the many individuals involved with the discovery of Ontario's archaeological resources, the trends outlined above suggest that much has been and continues to be accomplished. The fruits of that labour will now be summarized.

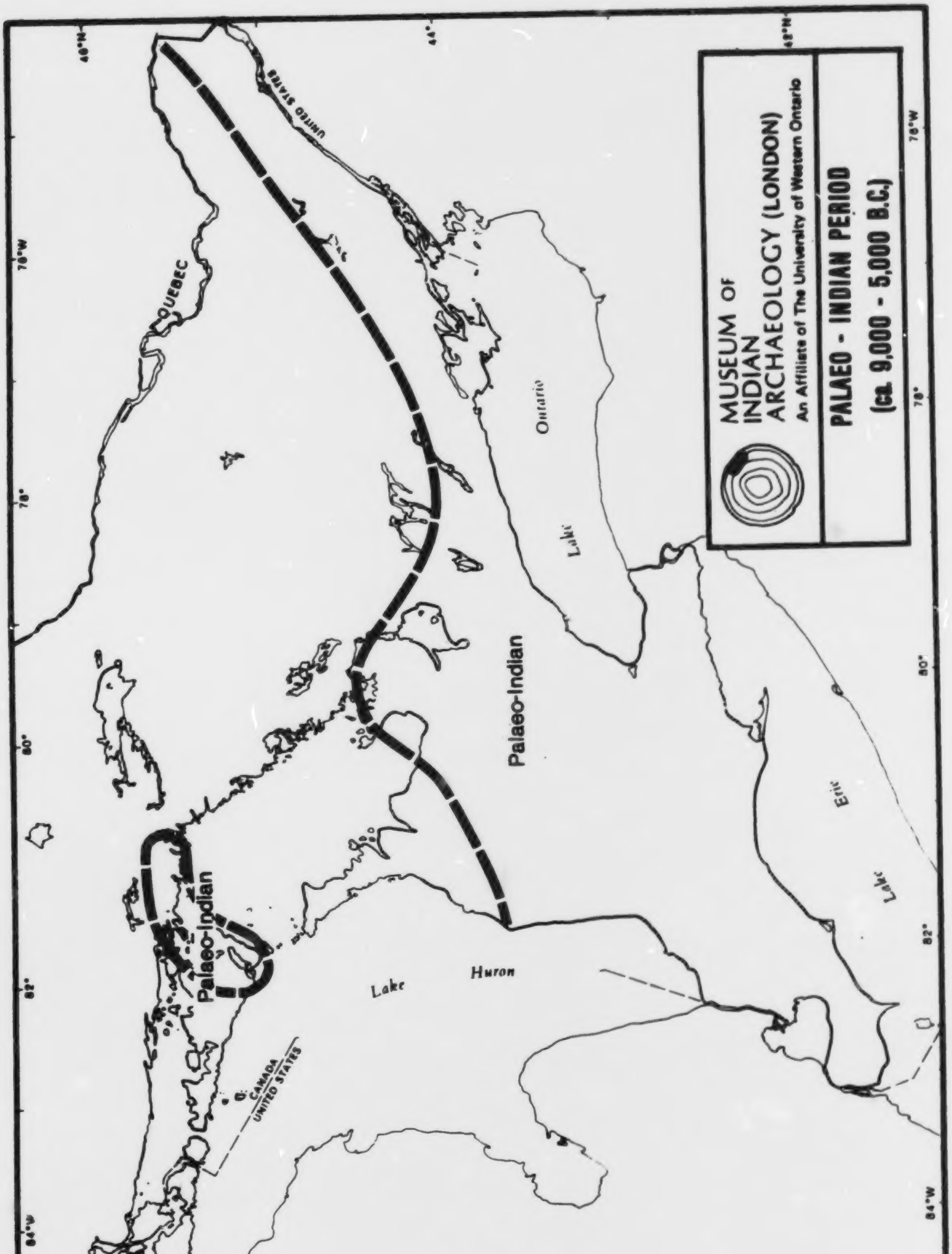
4.2 Cultural Chronology

The study area includes the land-based territory south of the 46th Parallel in what is generally termed southern Ontario. In the presentation that follows, cultures that are aligned to the south will be emphasized, even though these cultures interacted with those in northern Ontario at all time levels. Four periods are currently used to chart the development of Native cultures in southern Ontario: Palaeo Indian, Archaic, Woodland and Historic. These will be briefly described in the following sections. Several published summaries on southern Ontario prehistory have been used as guides (Mason 1981; Trigger 1976; J.V. Wright 1972b).

4.2.1 Palaeo Indian (9000-5000 B.C.)

The first occupation of Ontario began as early as 9000 B.C. with the arrival of cultures of the Palaeo Indian period (Map 3). Following the retreat of the glaciers and until around 5500 B.C., the southern Ontario environment was in transition from tundra-like to today's (or at least pre-European settlement) configuration. Vegetation and drainage systems were being established, and, therefore, the habitable environment was different from the present.

What is known about the Palaeo Indian inhabitants comes from research done in only a few locations within the study area (Map 2:I). These data suggest that these people probably existed as small, highly mobile (and


MUSEUM OF
INDIAN
ARCHAEOLOGY (LONDON)
An Affiliate of The University of Western Ontario
PALAEO - INDIAN PERIOD
(ca. 9,000 - 5,000 B.C.)
QUEBEC
UNITED STATES
Palaeo-Indian
Palaeo-Indian
Lake Ontario
Lake Huron
Lake Erie
CANADA
UNITED STATES
46°N
44°
84°W
82°
80°
78°
76°W
46°N
44°
84°W
82°
80°
78°
76°W

Map 3

nomadic) bands, most likely extended family groups, which ranged over large tracts of land in pursuit of migratory game such as caribou. Their sites can be small findspots consisting of chipping detritus and/or isolated tools or projectile points, or large, somewhat diffuse habitually-used living sites spread over several acres and close to strategic hunting locations. A determining factor for the placement of these large sites seems to have been an unobstructed view of the surrounding terrain for purposes of spotting game; such locations would be on elevated peninsulas, beach ridges, terraces, and off-shore islands or bars near margins of post-glacial lakes. The presence of flat marshy land due to recent draining, which would occur below these spots, would have provided good grazing land for game, especially caribou.

Artifacts characteristic of these sites include chipped stone projectile points, knives, gravers and scrapers. Projectile points are lanceolate-shaped, and the early varieties are fluted while the later ones are not. Although lithic artifacts are usually the only type discovered, other raw materials were most likely used but have not survived over time.

During the estimated 4000 year occupation of southern Ontario by Palaeo-Indian peoples, changes occur in the projectile point styles that suggest concomitant changes in hunting technology. This in turn seems to be a likely response to the changing constraints being imposed by the environment. Archaeologists do not yet see a clear line of development from the earliest to the latest Palaeo-Indian groups; the evidence argues, perhaps, for the intrusion of the later groups into the study area. Needless-to-say, much research is still required to more fully understand the Palaeo Indian period.

4.2.2 Archaic Period (5000-1000 B.C.)

After approximately 5500 B.C., modern environmental conditions were nearly established and prehistoric lifeways were undergoing change. In the period from 5000 to 4000 BC, there is little evidence for this transition. The archaeology of this period is poorly understood and information comes mainly from isolated findspots which indicate evolving styles of side-notched, corner-notched, basally-notched and serrated projectile points. The most important cultural manifestation of the Archaic period occurs from circa 4000 to 1000 B.C.

By 4000 B.C., modern drainage patterns and forest, floral, and faunal associations were present creating a rich and varied environment for habitation. Archaic sites are found in a wide variety of locations: between drainage systems (often some distance from available water), on stream and river banks, at stream/river junctions, on shores of ponds and small lakes, around estuaries, and on islands (Map 2: K and N). Large habitation sites are typically located where riverine/lacustrine, lowland (marsh or swamp) and forest eco-zones meet (Map 2: II). Small isolated sites, such as hunting sites, can be located almost anywhere, especially on elevated ground, and not necessarily near water. The diversity of site locations indicates an expansion of knowledge about using locally available resources.

The Archaic artifact inventory reflects this expanded adaptation to new resource zones. Tools associated with hunting and food preparation (i.e. projectile points, scrapers, knives, etc.) continue, but woodworking tools (chipped stone drills and ground stone axes, adzes, and gouges) and fishing tools (hooks and net-sinkers) appear. Artifacts made of copper imported from Lake Superior indicate the presence of long-distance trade and/or contact. Projectile point types begin to take on regional styles suggesting the development of cultural groups, and, indeed, along the north shore of Lake Ontario (as well as along the St. Lawrence and into New York) and east shore of Lake Huron the Laurentian and Inverhuron cultures have been defined (Map 4).

Throughout the region, there is a noticeable increase in Archaic artifacts and sites which suggest that an overall population increase resulted from a more stable and reliable resource base. Settlements were still not permanent, but were repeatedly used and for longer periods during the annual cycle. Group size varied with seasonal resource availability. An increased sense of territoriality becomes evident as suggested by the appearance of regionally-distinct cemetery burial patterns.

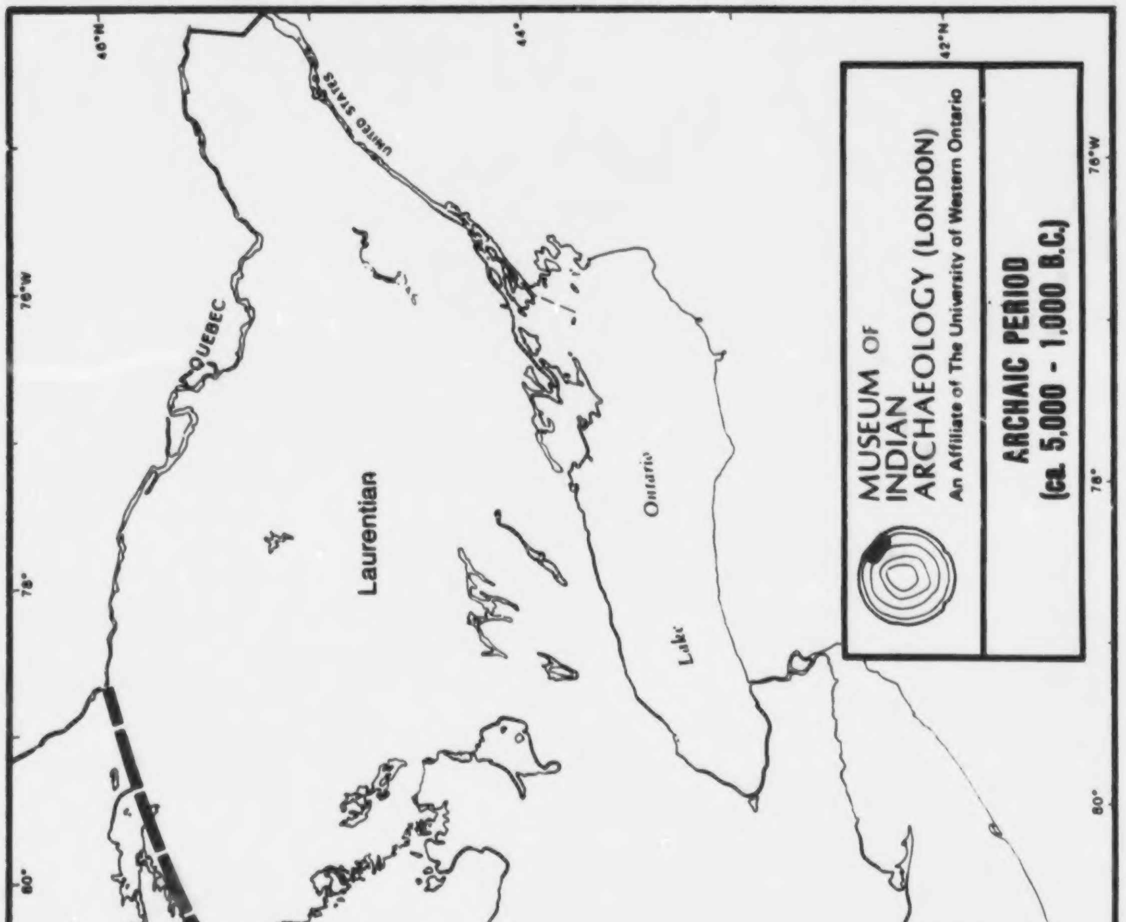
Around 1000 B.C., the Archaic period ends with the introduction of a new technology: pottery. Although this marks the beginning of the Woodland period, the basic lifeway patterns continued.

4.2.3 Woodland (1000 B.C. - A.D. 1650)

Archaeologists have divided the Woodland period into three sub-periods: Initial, Transitional, and Terminal. These sub-periods chart a significant series of developments for cultures in southern Ontario.

The Initial Woodland period encompasses the time span from 1000 B.C.-A.D. 500. Although this period begins by convention with the addition of pottery to an essentially Archaic subsistence and settlement pattern, nowhere in Ontario has a site with pottery been absolutely dated that early. Between 1000-300 B.C., burial ceremonialism becomes well expressed for the first time as elaborate grave goods such as birdstones and pendants made from ground stone, cache blades, beads and other personal objects are included with the burials; status differentiation also becomes increasingly evident. Although evidence for territorality is present as seen through the development of regional artifact styles, there was a significant amount of long-distance trading and inter-cultural interaction underway, the exact nature of which is unclear. Centred on the Niagara Peninsula and the St. Lawrence River, a discrete Meadowood culture has been defined but does not appear to expand far north into the rest of southern Ontario.

From approximately 300 B.C.-A.D. 500 archaeologists recognize at least three regional cultural manifestations (Map 5). Encompassing a large region centred on the Lake Ontario drainage, the Point Peninsula culture continued many of the basic Late Archaic subsistence and settlement patterns. Burial patterns were further elaborated by the construction of burial mounds in selected regions of the cultural distribution (Map 2:N). Upon excavation these burial mounds reveal abundant evidence of mortuary ceremonialism and social differentiation. Since these mounds are located in very rich ecological localities where


MUSEUM OF
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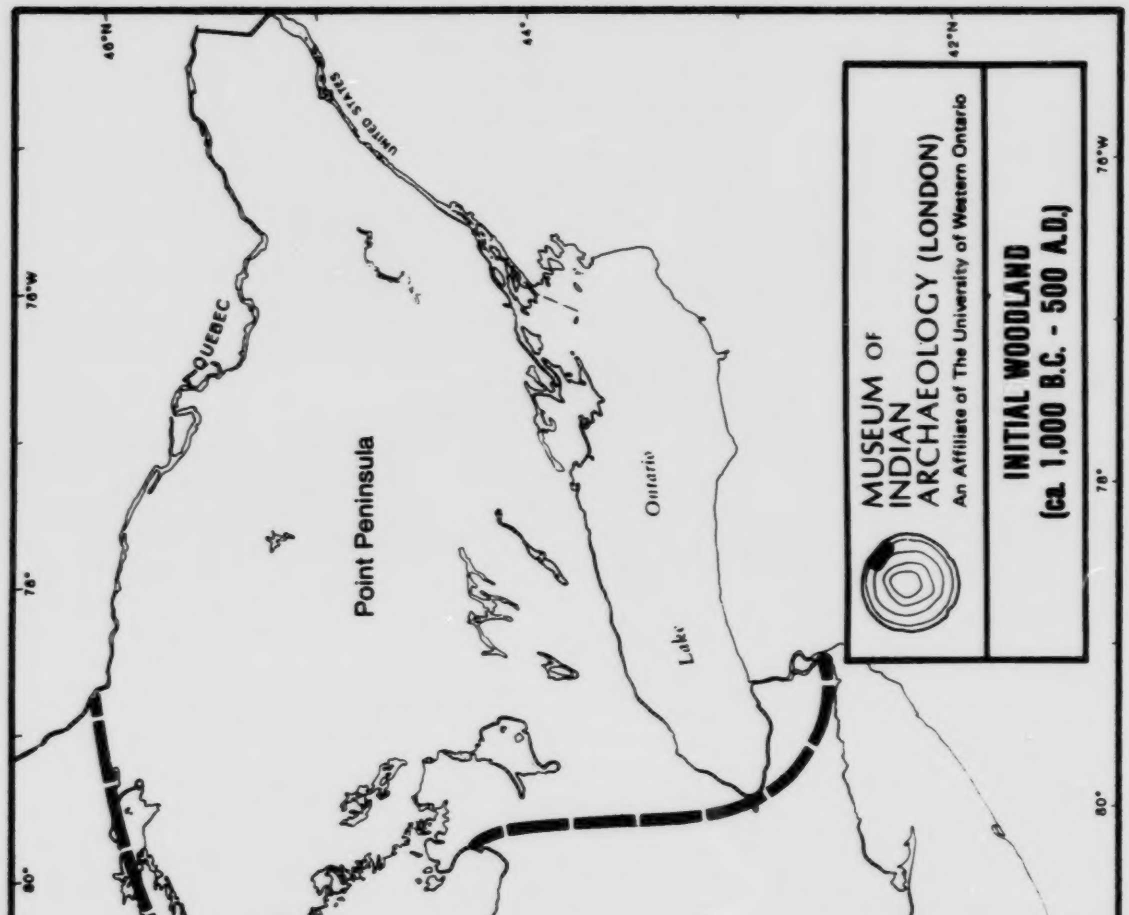
ARCHAEOLOGY (LONDON)
An Affiliate of The University of Western Ontario
ARCHAIC PERIOD
(ca. 5,000 - 1,000 B.C.)
Laurentian
Inverhuron
QUEBEC
UNITED STATES
CANADA
UNITED STATES
Lake Ontario
Lake Huron
Lake Erie
46°N
44°
42°N
84°W
82°
80°
78°
76°W

Map 4


MUSEUM OF INDIAN ARCHAEOLOGY (LONDON)
An Affiliate of The University of Western Ontario
INITIAL WOODLAND
(ca. 1,000 B.C. - 500 A.D.)
Point Peninsula
Saugeen
Western Basin
QUEBEC
UNITED STATES
CANADA
UNITED STATES
Lake Ontario
Lake Erie
Lake Huron
46°N
44°
42°N
76°W
78°
80°
82°
84°W

Map 5

harvestable foods such as rice and shellfish seem to have been important, there is some evidence to suggest that statused individuals were controlling the acquisition of these resources. Major Point Peninsula sites are also located along large waterways where fishing seems to have been the dominant subsistence activity.

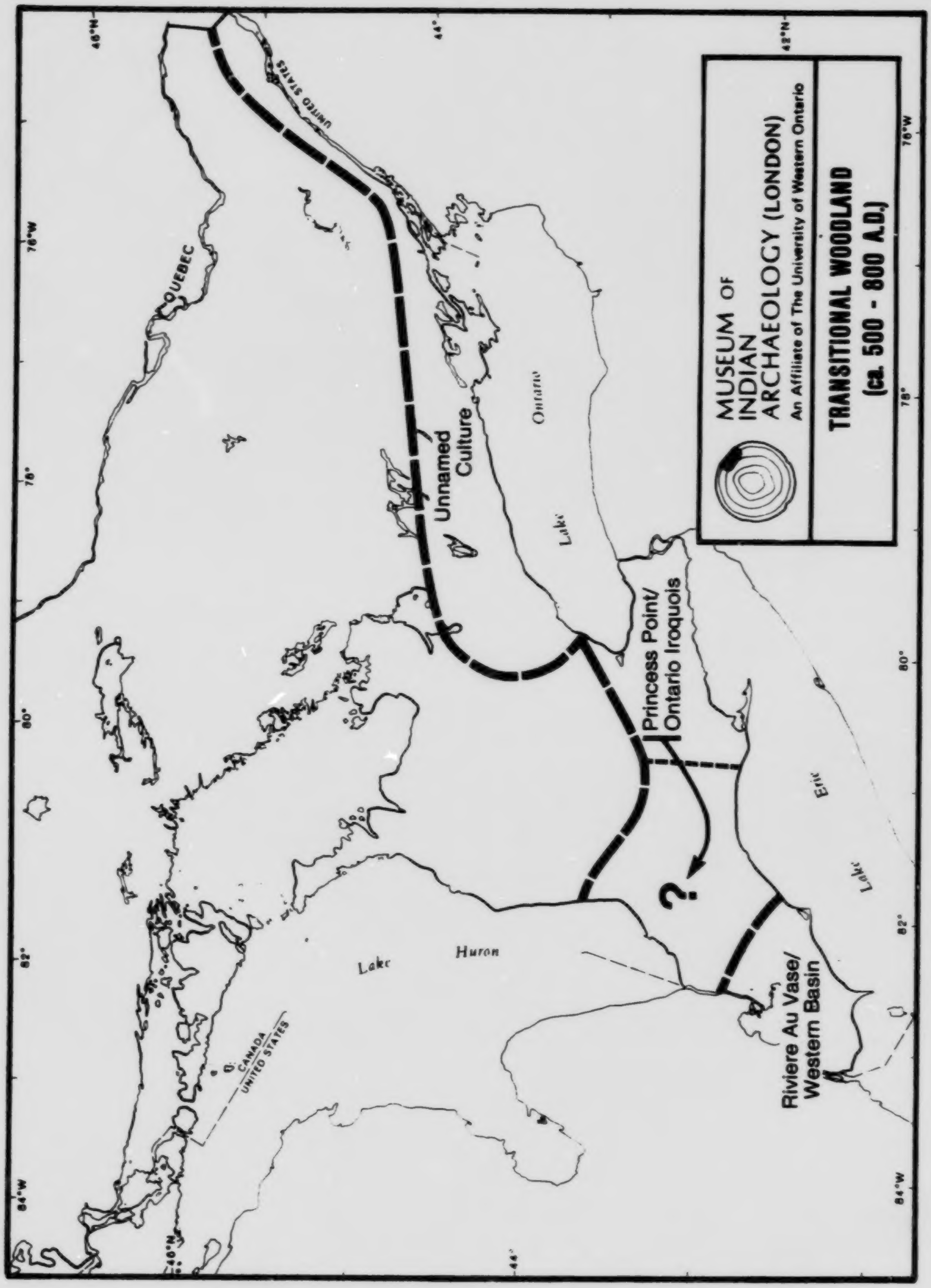
Elsewhere in southern Ontario, the Saugeen culture flourished. Sites of this culture are centred on the Lake Erie and Huron drainages and current data suggest that fishing was the predominant economic activity since the major sites are located beside river rapids (Map 2:Y). Although burial ceremonialism and status differentiation were not as elaborate as in the Point Peninsula culture, graves were accompanied by a rich assortment of exotic goods indicative of long-distance exchange with foreign groups.

In extreme southwestern Ontario, the Western Basin culture has just been recognized (Map 2:A). Although data is still sketchy, sites of this culture depict a hunting-gathering-harvesting/collecting economy in which burial cermonialism was not prominent.

The Transitional Woodland period begins around A.D. 500 when cultures in certain areas of southern Ontario began experimenting with corn and other cultigens in a form of incipient horticulture (Map 2:J). Ceramic and lithic styles portray a new and possibly developmental manifestation known as the Princess Point culture. Although this experimentation would anticipate a shift in the subsistence strategy which is characteristic of the Terminal Woodland period, it probably did not immediately alter the subsistence or settlement pattern of the preceding Initial Woodland period. However, by approximately A.D. 800, the major habitation sites were shifting away from locations adjacent to rivers/lakes and marshes onto higher ground off of minor tributaries. Settlements were becoming more permanent, and a noticable increase in overall population is indicated.

Regional manifestations during this period are not well known. In extreme southwestern Ontario (Map 6), the Riviere au Vase culture has been defined. Current data suggest that this culture is part of a line of development (evolving out of the Western Basin culture) which is different from that occurring elsewhere in the province. The Western Basin Tradition involved a sequence of occupations for the area around the western end of Lake Erie lasting to around A.D. 1400. It is presumed that this tradition was Algonkian, whereas Princess Point and an as yet unnamed culture along Lake Ontario formed the base of the Ontario Iroquois Tradition which eventually evolved into the Native cultures contacted by Europeans in the 1600's.

The Terminal Woodland period begins around A.D. 800 and marks the appearance of sedentary villages which were inhabited year-round. These villages contain numerous dwellings (which housed extended family units) and their arrangement became increasingly structured over time. These villages are palisaded, suggesting a strong notion of territoriality, and over time this palisading became a definite defensive consideration. Sites were located away from navigable waterways, and, by A.D. 1350, there is abundant evidence that internecine warfare was present.


MUSEUM OF INDIAN ARCHAEOLOGY (LONDON)
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TRANSITIONAL WOODLAND
(ca. 500 - 800 A.D.)
QUEBEC
UNITED STATES
CANADA
UNITED STATES
Unnamed Culture
Princess Point/ Ontario Iroquois
?
Riviere Au Vase/ Western Basin
Lake Ontario
Lake Huron
Lake Erie
46°N
44°
42°N
44°
46°N
76°W
78°
80°
82°
84°W

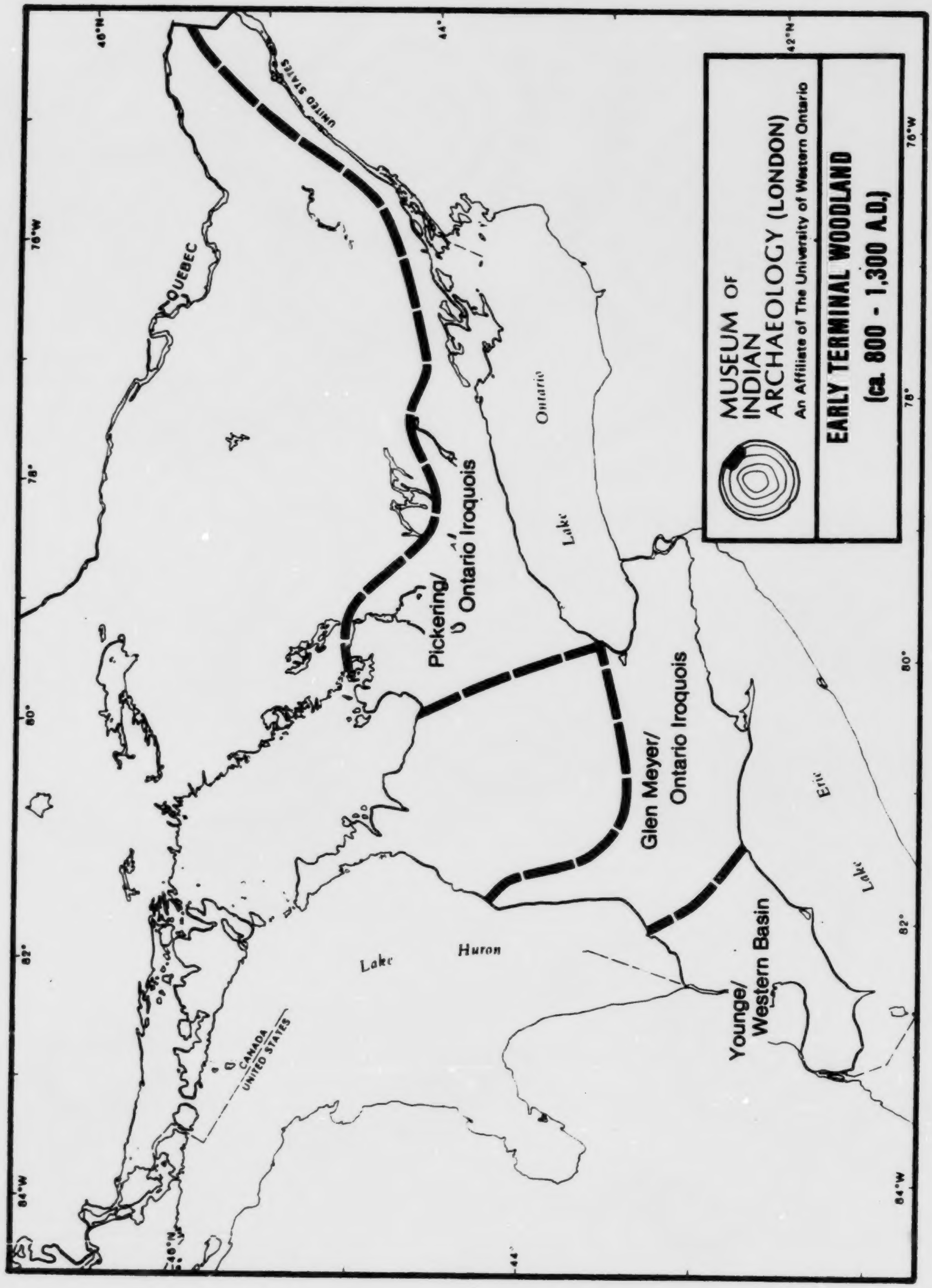
Map 6

Subsistence patterns show an increasing reliance on corn and this was later supplemented with beans and squash. Throughout the Terminal Woodland period, however, game, fish and collected foods continued to be important.

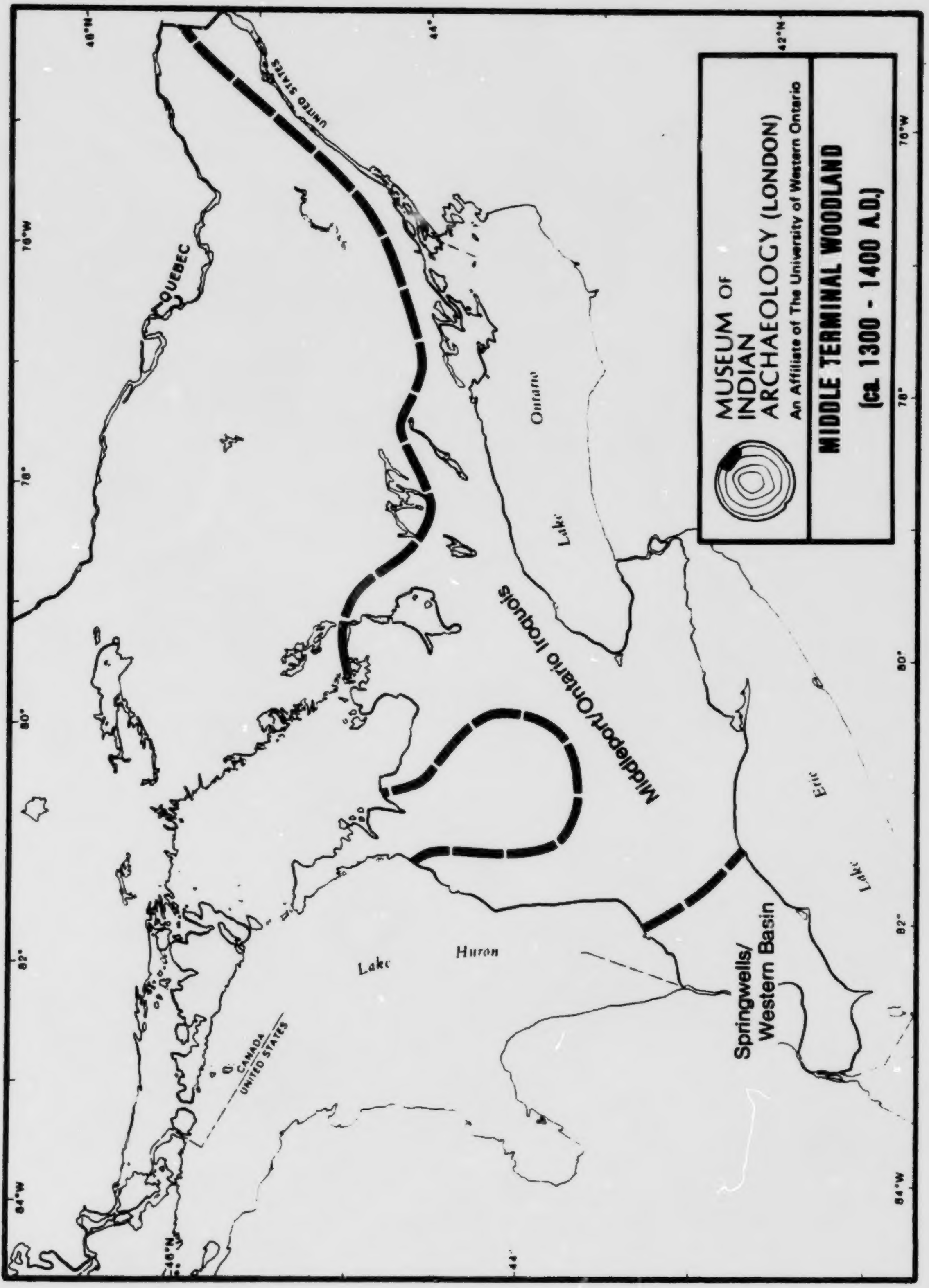
Correlated with the shift to horticulture was a development of settlement patterns that were unique to the Terminal Woodland period. Early in the period, only the lighter, sandier soils were used because they were the easiest to work but, as these became exhausted, the heavier, clayey soils were utilized. The land was cleared by the slash-and-burn method, but lacking fertilizers to rejuvenate the soil, it soon lost its productivity and necessitated a shift to new, uncleared land. Over a period of 10-25 years, the land under cultivation was eventually located some distance from the main villages requiring small satellite hamlets to be built. These were only occupied on a seasonal basis to service the fields. Seasonal hamlet sites were also established near fishing and game resources. Although these villages were occupied year-round and over an extended period of time (10-25 years), the actual population fluctuated annually as a variety of economic, social and aggressive activities were carried out.

Archaeologists have identified several developmental phases within the Terminal Woodland period during which regional manifestations are apparent: Early - Younge (Western Basin) and Glen Meyer and Pickering (Ontario Iroquois) cultures: A.D. 800-1300 (Map 7); Middle - Springwells (Western Basin) and Middleport (Ontario Iroquois) cultures: A.D. 1300-1400 (Map 8); and Late - Fort Meigs (Sandusky) and Prehistoric Neutral and Prehistoric Huron (Ontario Iroquois) cultures: A.D. 1400-1650 (Map 9).

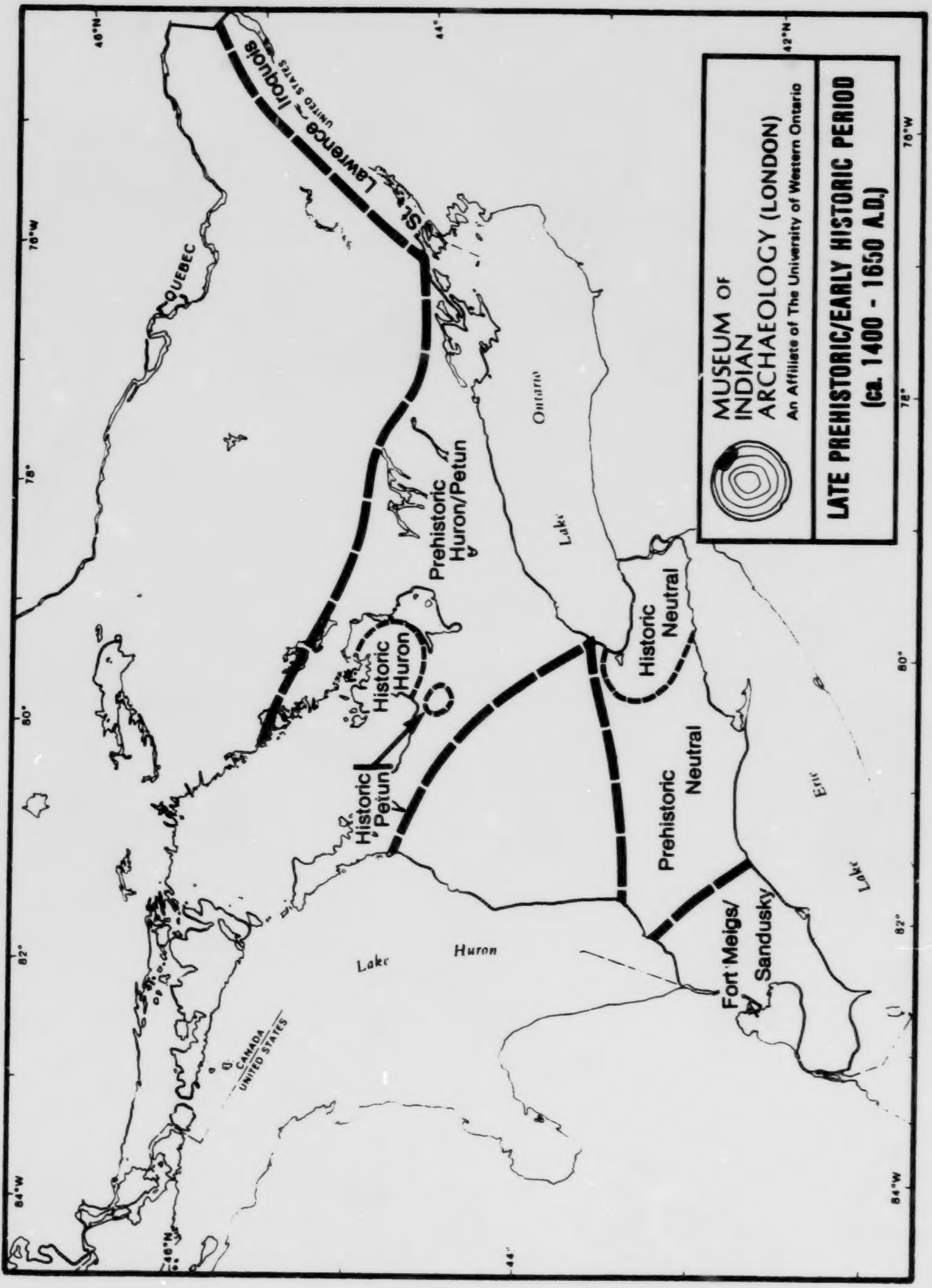
By A.D. 1550, indirect European contact through trade was being felt. As the trade became more lucrative during the 1600's, several tribal groups manoeuvred to take control of the trade away from neighboring tribes. Along the north shore of Lake Ontario, the Huron were successful at this, but it necessitated a movement and consolidation of their population into the Lake Simcoe area (Map 2:V). Above the Niagara Escarpment and west of Burlington as well as around Hamilton (Map 2:J), the Neutral were also consolidating their population but were not actively participating in the trade with the French because of pressure from the Huron (Map 9). From 1600 to 1650, the competition for European trade pitted the Huron and French against the New York Iroquois and Dutch; the objects of the trade were beaver pelts on one hand, and European commodities on the other. Over a period of about five years (1650-1655) the New York Iroquois attacked and dispersed the Ontario Iroquois groups from Lake Simcoe and later from around the Hamilton-Burlington area. By A.D. 1655 the indigenous cultures that had developed in southern Ontario no longer existed intact, and this date can be used to signal the beginning of the Historic period.


MUSEUM OF INDIAN ARCHAEOLOGY (LONDON)
An Affiliate of The University of Western Ontario
EARLY TERMINAL WOODLAND
(ca. 800 - 1,300 A.D.)
Pickering/ Ontario Iroquois
Glen Meyer/ Ontario Iroquois
Younge/ Western Basin
Lake Ontario
Lake Erie
Lake Huron
QUEBEC
UNITED STATES
CANADA
UNITED STATES
46°N
44°
42°N
84°W
82°
80°
78°
76°W

Map 7


MUSEUM OF
INDIAN
ARCHAEOLOGY (LONDON)
An Affiliate of The University of Western Ontario
MIDDLE TERMINAL WOODLAND
(ca. 1300 - 1400 A.D.)
Middleport/Ontario Iroquois
Springwells/
Western Basin
Lake Huron
Lake Ontario
Lake Erie
QUEBEC
UNITED STATES
CANADA
UNITED STATES
46°N
44°
42°N
84°W
82°
80°
78°
76°W

Map 8


MUSEUM OF INDIAN ARCHAEOLOGY (LONDON)
An Affiliate of The University of Western Ontario
LATE PREHISTORIC/EARLY HISTORIC PERIOD
(ca. 1400 - 1650 A.D.)
QUEBEC
St. Lawrence Iroquois
UNITED STATES
Prehistoric Huron/Petun
Historic Huron
Historic Petun
Historic Neutral
Prehistoric Neutral
Fort Meigs/ Sandusky
Lake Ontario
Lake Huron
Lake Erie
CANADA
UNITED STATES
46°N
44°
42°N
76°W
78°
80°
82°
84°W

Map 9

4.2.4 Historic (A.D. 1650-1900)

The period immediately following the dispersals of the 1650's witnessed an attempt by the New York Iroquois to locate trading centres along the north shore of Lake Ontario. The Oneida, Cayuga, and Seneca sought to establish these centres, at the encouragement of the English and Dutch, at key portage routes in order to compete with French traders. After fierce competition, the French finally eradicated them in 1695 and took control of the trading posts. Native groups which were formerly allied with the Huron and Neutral began to settle along the north shore of Lake Ontario and Georgian Bay. The Mississauga settled in the former area, and the Credit River region was one favourite locality.

By A.D. 1900, European settlement in most areas was complete and Native reservations had been established.

5.0: ARCHAEOLOGY AND THE FACILITIES DEVELOPMENT PROCESS

This section will discuss how archaeology can affect the Facilities Development Process by comparing two types of archaeological case studies. These case studies illustrate how archaeology was involved in the planning and development of specific projects. Archaeological data pertinent to each case study were extracted from the available literature and individually summarized in Section 11.0. Highlights from each case study have been included under the "Comments" heading.

5.1 Case Study Approach: Comparisons

In the first or passive type of case study, only existing and registered archaeological resources within a general study region are inventoried by checking site record files and current researchers. Distributional maps are then prepared which indicate high density and therefore sensitive areas. This type of inventory is designed more for long-term planning so these high density zones can be singled out and either avoided or properly examined (through archaeological survey and/or mitigation).

In the second or active type of inventory, a specific project area is subjected to intensive archaeological survey as a means of determining the total range of archaeological resources within that area. This type of inventory is also useful for long-term planning, but is usually undertaken when more immediate impact is scheduled, such as the development of a park or the initiation of a construction project.

In the two examples of a passive type of inventory referred to in this report (Section 11.0: 8,10) it is clear that there are numerous high density zones of aboriginal occupation. To a large degree, they reflect the research interests of amateur and professional archaeologists who, over the past one hundred years, have singled out these areas for intensive examinations. The intervening areas of low or non-existent archaeological site density, then, do not necessarily reflect a lack of aboriginal occupation, but a corresponding lack of archaeological investigation. These latter areas would be obvious foci of archaeological attention should development be planned within their boundaries.

The seven examples of an active type of inventory referred to in this report (Section 11.0: 1-7) all demonstrate the importance of preceding development of any kind with intensive archaeological reconnaissance. In all cases, the number of previously registered sites within each region was low, indicating a perhaps erroneous conclusion that aboriginal occupation was light. However, after detailed surveys were conducted, it became clear that the numbers of sites within each case study were high. It must be clarified though that not all of the sites have research potential, that is, are able to contribute significantly to the cultural history of the areas involved (i.e. the sites represent isolated finds). As the case studies detail, the richness (i.e. density) and variety of archaeological resources contained within each has much to do with ecological factors such as topography, availability of natural resources (food, water, arable land, forest products for building, chert, etc.), and location along communication routes.

In the comparisons presented above, it is apparent that an informal assessment strategy is suggested which proceeds from a more general type of inventory (i.e. Case Studies 8-10) to a more specific type (i.e. Case Studies 1-7). A more detailed examination approach will now be presented involving three procedural phases: background research (Phase I), archaeological survey (Phase II) and mitigation (Phase III).

5.2 Phase I: Background Research

Background research is usually initiated as Phase I in the archaeological examination strategy after one or more generalized study regions have been selected. The purpose of Phase I is threefold: to ascertain existing archaeological resources; to estimate and rank areas of archaeological site potential; and to recommend procedures for dealing with areas of high archaeological sensitivity for future planning stages. Case Studies 8-10 (Section 11.0) are examples of this approach.

5.2.1 Existing Archaeological Resources

Data on existing archaeological resources are compiled from a number of sources. The most important is the Archaeological Site Data Base of the Regional Archaeologists within the Archaeology and Heritage Planning Branch, Ministry of Citizenship and Culture (see description Section 3.1). All registered site locations within the study region(s) that are contained on the Ministry's 1:50000 base maps are transferred to a set of project 1:50000 base maps. Site record files of current researchers and institutions such as museums, universities, and archaeological societies are also consulted for pertinent but unregistered site data. Finally, discussions with the various Regional Archaeologists and other individuals can identify numerous local informants (i.e. amateur archaeologists and/or collectors) who might provide additional, unregistered site information for the study region. These new data are also placed on the project base maps.

5.2.2 Estimation and Ranking of Archaeological Site Potential

This component involves a synthesis of information from two basic sources: archaeological and earth science. All available published and unpublished archaeological documentation for the study region and vicinity are collected. In addition to the site distributional information secured from the Ministry, these reports provide data on the types of artifacts and temporal placement of the archaeological occupation within the study region and the subsistence/settlement patterns characteristic of them. Earth science data fulfills an important role in estimating site potential by helping to set forth the environmental parameters within which the archaeological occupation existed. Types of data used include:

1. physiography: eg. soils, topography, surficial geology

2. hydrology: type and location of water sources

3. vegetation: distribution of types of vegetation such as forests (eg. white pine stands), rice beds, marshland, etc.

4. natural resources: chert outcrops, type and quantity of food resources

These two types of data, plus a knowledge of archaeological trends in regions similar to the study region, are then used to produce an archaeological profile of the study region. This profile will include the identification of areas of archaeological sensitivity defined by the known distribution of archaeological sites and/or areas of potential archaeological occupation. Although no truly objective way exists to rank the latter areas, they are placed within a continuum ranging from low to high sensitivity. Generally speaking, areas that normally are ranked as having a high archaeological site potential include, among others, all lands within 100 meters of a watercourse.

5.2.3 Recommendations

Once archaeological sensitivity has been assessed and ranked within the general study region, specific recommendations for further planning can be made. For instance, zones of high archaeological sensitivity should be avoided whenever possible while those of medium to low sensitivity become increasingly acceptable for use in the Facilities Development Process. In all cases, however, no work should proceed until some type of archaeological survey is undertaken. This subject will now be discussed.

5.3 Phase II: Archaeological Survey

Archaeological survey is usually initiated as Phase II in the archaeological examination strategy after a particular study area has been selected. This phase involves a physical examination of the project area using methods that vary with the vegetation and/or archaeological sensitivity.

5.3.1 Survey Strategy

Vegetation is commonly classified (for archaeological purposes) as being open or closed. Open vegetation consists of ploughed land or fields planted in beans, corn, or a similar crop. This type of vegetation can be effectively assessed using the transect survey. This involves spacing individuals at intervals, depending on the intensity requirements of the survey, and walking along the crop rows. Surface material is then collected and their locations are recorded. Closed vegetation consists of land in bush or fence rows, or fields left in pasture, grass or planted in crops such as wheat. This type of vegetation can only be assessed by test-pitting (although crops are usually avoided). This involves the excavation of small 30 cm. squares into the subsoil at regularly-spaced intervals. Back dirt is checked for artifacts, and if any are found, then the square's location is recorded.

The archaeological survey should ideally be multi-staged, that is, executed over several seasons, so that certain areas can be examined more than once. Often a field that was initially in closed vegetation such as wheat or grass will be cultivated in subsequent seasons with a crop such as corn or beans. Because test-pitting is not as effective as transect survey, it is advisable to utilize transect survey whenever possible to improve assessment potential. This can be accomplished if several survey seasons are available. Poorly defined sites located in cultivated fields can be re-examined after fall ploughing. This allows the archaeologist to augment a perhaps sparse artifact inventory so that a more accurate understanding of the site's areal distribution and cultural affiliation can be obtained. This information is essential when evaluating the site for subsequent mitigation or avoidance procedures. The optimum approach is to conduct the surveys in the spring and fall of the same year or in successive spring or fall seasons a year apart. During these seasons the fields are ploughed or newly seeded, and observation conditions are excellent.

By allowing greater access to open vegetation, multi-stage survey can be more cost-effective than single season survey. Since test-pitting is more labour-intensive, it is also more costly than transect survey. Furthermore, if highly sensitive areas in closed vegetation have to be examined by test-pitting then the survey interval must be reduced which would greatly add to the assessment cost. In the long-run, then, the multi-stage survey approach offers better assessment opportunities at lower cost, and, in turn, more reliable results.

The purpose of the Phase II archaeological survey is to identify the nature of the archaeological resources within a project area. Previously registered sites may have to be re-located in the field and mapped and/or surface-collected, if necessary, to re-verify their status. For all sites within the project area, the primary objectives of the survey are to delimit the boundaries of each site and to estimate its cultural affiliation. The former can be accomplished by conducting a controlled surface pick-up that is, by mapping the location of each artifact that is surface-collected. Aboriginal midden deposits or activity areas can be discerned using this technique, and the location of features like these is important when planning mitigative excavation. The latter objective can be accomplished by securing a sample of diagnostic artifacts from the site, such as rim sherds or projectile points. These contain stylistic traits which can be relatively dated to a cultural period.

5.3.2 Recommendations

Based on the results of Phase II, a detailed set of site-specific recommendations can be generated which will outline what mitigative procedures are required and in what priority they would have to be implemented. Those archaeological sites not requiring further study would be listed.

Finally, for archaeological resources located within a project area and which are sensitive to mitigate, recommendations urging avoidance procedures can be proposed. Resources such as Native burial grounds or large undisturbed village sites are obvious examples.

5.4 Phase III: Mitigation

As a rule, the destruction of valuable archaeological resources should be avoided in the Facilities Development Process. However, if that is not possible, then mitigative excavations must be performed on that portion of the site endangered by disturbance. In this section, a mitigation strategy will be discussed in two parts: an initial test excavation stage, and a follow-up complete excavation stage.

5.4.1 Test Excavations

In mitigation it is expedient to sample the sub-surface deposits before launching a total salvage effort. The reason is simple: sometimes non-archaeological (i.e. post-depositional) forces have obliterated some or all of the features indicative of the former occupation. A few examples are deep ploughing, installation of tile drains, and erosion. While surface-collected artifacts might give the impression of a major site, the sub-surface features may yield only sparse information. The sampling procedures apply to both disturbed (i.e. cultivated fields) and undisturbed (i.e. woodlots, fence lines) deposits.

For undisturbed deposits, small excavation units (1 meter squares) are excavated across the site. They are placed in order to locate the site boundaries, to estimate the productivity of artifacts in the topsoil zone, and to assess the presence of sub-surface occupational features such as pits, hearths, post-moulds or middens. All contents of the squares are recorded in detail.

For disturbed deposits, a 2 meter-wide cross-trench is placed across the site. Its purpose is to locate the limits of the site and to gain a preliminary understanding of the settlement pattern (i.e. the arrangement and spacing of pits, posts, and therefore, structures within the site). Because of the area involved, the plough zone is usually stripped off by mechanical equipment so that the subsoil is exposed. This is then scraped with flat shovels and archaeological features are recorded and excavated.

5.4.2 Complete Excavation

Completing the mitigation on a site basically involves expanding the test excavations to include the entire site or portion thereof which will be impacted.

For undisturbed deposits this could simply be a matter of completely excavating the remaining portions of a fence row or could involve the total excavation of a 5 acre village within a woodlot.

As can be imagined, the costs of the latter would be staggering, but it is a reality that must be confronted.

For disturbed deposits, this step involves the stripping off of the remaining disturbed deposits so that the subsoil zone can be examined. All settlement pattern would be recorded, and all archaeological features would be excavated.

5.4.3 Analysis of Results

Once the fieldwork is completed, all artifactual material needs to be washed, catalogued and analyzed. Settlement pattern data has to be compiled so that site maps can be drawn. Supplemental analyses of floral and faunal remains need to be initiated. Finally, all the site data must be interpreted in a report which can be circulated for professional comment.

5.4.4 Comment

The mitigation of an impacted archaeological resource is a time-consuming and labour-intensive endeavour. Not only is it costly, but it requires enough lead time so that it can be accomplished without disrupting a construction schedule. For that reason, it is recommended that at least one season (April - October) be set aside for mitigative excavations in case they are required.

6.0: IMPLICATIONS OF THE ONTARIO HERITAGE ACT, THE ENVIRONMENTAL ASSESSMENT ACT, AND THE DISCOVERY OF NATIVE BURIALS ON THE FACILITIES DEVELOPMENT PROCESS

6.1 Introduction

This section deals with the various legal implications of heritage resources (prehistoric and historic aboriginal sites and non-aboriginal sites) including Native and non-Native burials that could potentially affect the Facilities Development Process. Of primary concern are the laws, guidelines and policies set forth in the Ontario Heritage Act, the Environmental Assessment Act, and the Ministry of Citizenship and Culture's working policy regarding the discovery, excavation and analysis of Native burials.

6.2 The Ontario Heritage Act

In 1975, the Ontario government passed Bill 176, "An Act to Provide for the Conservation, Protection and Preservation of the Heritage of Ontario", also known as "The Ontario Heritage Act, 1974". This act was subsequently revised in 1981 under "Revised Statutes of Ontario, 1980, Chapter 337".

The main legal implication of this act concerns the "stop order" clause covered in Section 62(1):

> 62(1) Where the Minister after consultation with the Foundation is of the opinion that property is of archaeological or historical significance and is likely to be altered, damaged or destroyed by reason of commerical, industrial, agricultural, residential or other development, the Minister may issue a stop order directed to the person responsible for such commercial, industrial, agricultural, residential or other development prohibiting any work on the property for a period of no longer than 180 days, and within that period the Minister or any person authorized by him in writing may examine the property and remove or salvage objects therefrom.

(In the above statement, Minister refers to the Minister of Citizenship and Culture (formerly Culture and Recreation), and Foundation refers to the Ontario Heritage Foundation.)

To avoid invocation of Section 62(1), it is obviously desirable to have qualified archaeologists assess a property prior to construction to determine if heritage resources are present and threatened by the development. Such assessments are further covered under the act in Section 48(1):

> Subject to subsection (2), no person shall carry out archaeological exploration, an archaeological survey or field work without a licence therefor issued by the

Minister under this part.

Archaeologists must obtain said licence through application to the Ontario Heritage Foundation, a crown corporation established by the Act, which has the following mandate:

(a) to advise and make recommendations to the Minister on any matter relating to the conservation, protection and preservation of the heritage of Ontario;

(b) to receive, acquire and hold property in trust for the people of Ontario;

(c) to support, encourage and facilitate the conservation, protection and preservation of the heritage of Ontario;

(d) to preserve, maintain, reconstruct, restore and manage property of historical, architectural, archaeological, recreational, aesthetic and scenic interest;

(e) to conduct research, educational and communications programs necessary for heritage conservation, protection and preservation.

6.3 The Environmental Assessment Act

The Environmental Assessment Act, 1975 and its Regulations (i.e. Ontario Regulation 836/76) include in their description and definition of environment certain man-made heritage components. Specifically, the Act states:

1(c) "environment" means,

(i) air, land or water,

(ii) plant and animal life, including man,

(iii) the social, economic and cultural conditions that influence the life of man or a community,

(iv) any building, structure, machine or other device or thing made by man,

(v) any solid, liquid, gas, odour, heat, sound, vibration or radiation resulting directly or indirectly from the activities of man, or

(vi) any part or combination of the foregoing and the interrelationships between any two or more of them, in or of Ontario;

An environmental assessment, including an assessment of man-made heritage, is required under the Act in conjunction with certain "undertakings". The Act defines an "undertaking" as:

> 1(o) (i) an enterprise or activity or a proposal, plan or program in respect of an enterprise or activity by or on behalf of Her Majesty in right of Ontario, by a public body or public bodies or by a municipality or municipalities, or
>
> (ii) a major commercial or business enterprise or activity or a proposal, plan or program in respect of a major commercial or business enterprise or activity of a person or persons other than a person or persons referred to in subclause (i) that is designated by the regulations;

As stated in Section 2 of the Act,

> "...the purpose of this Act is the betterment of the people of the whole or any part of Ontario by providing for the protection, conservation and wise management in Ontario of the environment."

Accordingly, the proponent of an undertaking is required to submit to the Minister of the Environment an environmental assessment (Section 5(1)). This assessment must contain the following:

> 5(3) (a) a description of the purpose of the undertaking;
>
> (b) a description of and a statement of the rationale for,
>
> (i) the undertaking,
>
> (ii) the alternative methods of carrying out the undertaking, and
>
> (iii) the alternatives to the undertaking;
>
> (c) a description of,
>
> (i) the environment that will be affected or that might reasonably be expected to be affected, directly or indirectly,
>
> (ii) the effects that will be caused or that might reasonably be expected to be caused to the environment, and
>
> (iii) the actions necessary or that may reasonably

> be expected to be necessary to prevent change, mitigate or remedy the effects upon or the effects that might reasonably be expected upon the environment,
>
> by the undertaking, the alternative methods of carrying out the undertaking and the alternatives to the undertaking; and
>
> (d) an evaluation of the advantages and disadvantages to the environment of the undertaking, the alternative methods of carrying out the undertaking and the alternatives to the undertaking.

In July 1978, the Ministry of the Environment issued a publication entitled "General Guidelines for the Preparation of Environmental Assessments". In 1980, the Ministry of Culture and Recreation prepared and submitted a supplement to those guidelines, specifically dealing with the man-made heritage component, entitled "Guidelines on the Man-Made Heritage Component of Environmental Assessments" (Weiler 1980). The summary of those supplemental guidelines is reproduced below.

> SUMMARY
>
> This summary is an abbreviated version of the main subjects of discussion in the Guidelines. Anyone wanting a fuller understanding of these subjects should refer to the main text.
>
> Man-Made Heritage and The Environmental Assessment Act
>
> The Minister of Culture and Recreation is concerned with the environmental planning process established by The Environmental Assessment Act, 1975, because of his responsibility under section 2 of The Ontario Heritage Act, 1974 for "determining policies, priorities and programs for the conservation, protection and preservation of the heritage of Ontario." Heritage resources include property of historical, architectural, archaeological, aesthetic, and scenic interest;
>
> Section 1(c)(iv) of the Environmental Assessment Act, 1975 makes it necessary in order to comply with the definition of environment contained in the statute to identify and evaluate those elements of the environment that are the works of man or the effects of his activities and which may be regarded as part of the province's heritage because of their influence on the social, economic and cultural life of Ontarians or the places where they live; and
>
> Section 5(1) of The Environmental Assessment Act, 1975 establishes two fundamental questions to be addressed with

the submission of an environmental assessment - is the information in the environmental assessment adequate to render it acceptable; and should the undertaking be given approval to proceed? Sufficient information concerning the man-made heritage component of the environment and the potential effects on it from an undertaking is an important part of this decision-making process.

Man-Made Heritage and the Content of Environmental Assessments

Section 5(3) of The Environmental Assessment Act, 1975 provides the basis upon which man-made heritage, as a component of environment, should be identified and evaluated. An environmental assessment should therefore include the following, presented in narrative and graphic form:

> In the description of the purpose and rationale for the undertaking, an explanation of why proposed change to any already well-known man-made heritage in the environment may be the undertaking, or an alternative method of carrying out the undertaking, or an alternative to the undertaking;
>
> In the description of the environment to be affected by the undertaking and alternatives, the way in which man-made heritage may determine the location and extent of the affected area;
>
> In the description of the environment to be affected by the undertaking and alternatives, a description of any man-made heritage in cultural landscape, built environment, and archaeological resources, as well as the public's expressed interest in such cultural properties;
>
> In the description of predictable effects on the environment of the undertaking and alternatives, a description of expected beneficial and adverse affects on man-made heritage resources and on the interests of Ontarians in such resources;
>
> In the description of actions necessary to prevent, change, mitigate, or remedy adverse effects on the environment from the undertaking and alternatives, a description of such actions considered necessary and appropriate for the conservation of man-made heritage resources;
>
> In the evaluation of the advantages and disadvantages of the undertaking and alternatives to the environment, an explanation of how man-made heritage resources have been ranked among other factors in deciding upon the desirability of the proposed change in the environment, and why any trade-offs involving either the destruction, or retention, or improvement of cultural property were considered necessary or appropriate (Weiler 1980:vii).

These guidelines further outline those components of a man-made nature which fall under the definition of "environment". These include both historic and prehistoric heritage resources. For purposes of this report, attention will focus on prehistoric (archaeological) heritage resources. The guidelines state:

> The necessary information for Archaeology includes the identification and evaluation of any feature that has one or more of the following attributes:
>
> > It has the potential through archaeological exploration, survey, or fieldwork to provide answers to substantive questions (i.e. relate to particular times and places) about events and processes that occurred in the past and therefore add to our knowledge and appreciation of history;
> >
> > It has the potential through archaeological exploration, survey, or fieldwork to contribute to testing the validity of general anthropological principles, especially those relating to the process of long term culture change and ecological adaptation, and therefore to the understanding and appreciation of our man-made heritage; or
> >
> > It is probable that various technical, methodological, and theoretical advances are likely to occur during archaeological investigations of a feature, alone or in association with other features, and therefore contribute to the development of better scientific means of understanding and appreciating our man-made heritage (Weiler 1980:8).

The nature and content of an archaeological assessment as part of an environmental assessment are described in the guidelines as follows:

> The process of making descriptions of man-made heritage for environmental assessments should begin, as discussed above, with consultation with the Ministry of Culture and Recreation on the available information. If there is no directly relevant information currently available from existing government or private sources, or if such information is seriously deficient, then it will be suggested to the proponent that he provide for, to some specified extent, original documentary or fieldwork research to develop the required information for the environmental assessment.
>
> The documentary component of research can involve the development of a body of data about the study area through the analysis of printed sources, manuscripts, records, and documents, as well as other material such as photographs, maps, and tape recordings. This work is usually done in archives, libraries, and similar institutions. Also included here could be the examination of communications or other documentation on public perceptions solicited by the proponent from the organizations and groups listed above. To assist in this

latter data-gathering process, it would be helpful for the proponent to circulate a questionnaire that clearly indicates the nature, purpose, and rationale for the proposed undertaking, and asks the respondent to identify those landmarks or special places of historic, scenic, or aesthetic interest in the affected area that he or she considers important in the lifeways, beliefs, or institutions of his or her organization or group. Questionnaires certainly do not have to be exclusively concerned with man-made heritage and are probably best utilized as part of a comprehensive public participation programme in the preparation of an environmental assessment. Moreover, there are other methods of determining public perception of man-made heritage such as sending individual letters specifically tailored to solicit the views of a particular group or organization; examining policy statements concerning specific heritage sites or heritage conservation in general in the promotional literature of organizations or groups; and observing the visible evidence in cultural properties that have been commemorated through public or private initiative by way of physical conservation or other development of a site, plaques or cairns on a site, signs on route to a site, or other means. These methods are by no means definitive or mutually exclusive.

The fieldwork component of research can involve one or more of the following:

cultural landscape analysis;

built environment survey; or

archaeological survey.

Cultural landscape analysis and built environment survey may often be incorporated as part of a proponent's already well-established fieldwork investigations of an area to be affected by a proposed project. Archaeology normally requires special provisions.

Cultural landscape analysis and built environment survey should begin with the examination of documentary data, maps, and aerial photographs, along with interviews with local people. This helps to pin-point the location of significant prospects of scenery and important visible features. Field recording is normally undertaken through sketch elevations and plans, photographs, detailed drawings of key elements, and maps.

Archaeological survey necessitates a thorough study of documentary information. It entails close collaboration with local people. The fieldwork programme itself must be adequately planned, funded, and staffed, and it should be attuned to the identification of both prehistoric and historic features. Without carrying out the examination of every square

> metre within the area to be affected by the undertaking and alternatives, the field programme should attempt to be both systematic and comprehensive. Fieldwork normally involves strategic walking of the terrain complemented by study of relevant maps and aerial photographs. More importantly, it involves soil sampling, surface collection, and test excavation. Some form of detailed examination is the only certain way to confirm the existence and meaning of early remains about which the documents are silent or non-existent. Since excavation involves the removal of evidence from its interpretative context, the skill and care with which the job is done are of primary importance. The process is both labour intensive and time consuming. For this reason it is preferable that disturbance of archaeological resources be kept to an absolute minimum. Archaeological exploration, survey, or fieldwork requires a licence under section 48 of The Ontario Heritage Act, 1974 (Weiler 1980: 8-9).

(Section 5.0 of this report outlined a multi-stage strategy for archaeological survey. Included in that section were details on mitigation and avoidance, which are discussed below.)

The guidelines contain specific recommendations to "prevent, change, mitigate, or remedy adverse effects on man-made heritage" should a significant archaeological site be discovered through an assessment. These are outlined below.

> The description of actions necessary to prevent, change, mitigate, or remedy adverse effects on man-made heritage in the environment should specify not only the mitigative measures themselves, but also the procedures required to monitor the predicted effects and prescribed mitigation measures during each phase of the undertaking. Migitation measures may themselves have adverse effects, which should also be identified.
>
> Mitigation measures and monitoring procedures must obviously be tailored to the nature and scope of each "Specific" (or individual) undertaking. It is important, however, that in every case the following be discussed:
>
> who is responsible?
>
> what cultural property is involved, and where is it?
>
> what is to be done, when, and for how long?; and
>
> what resources will be required to undertake the necessary actions?
>
> Moreover, the following principles should be kept in mind when describing actions necessary to prevent, change, mitigate, or remedy adverse effects on man-made heritage;

Known archaeological sites, or areas where such sites might reasonably be expected to exist, should be avoided and preserved;

Existing elements of the built environment should be retained and used wherever economically feasible and consistent with public health and safety;

The design and alignment of new roadways and service corridors should be in harmony with the surrounding area;

Division of land should be in harmony with the orientation and division of lots characteristic of the existing pattern in the surrounding area;

In built-up areas, new buildings developed as infill or for expansion should be in harmony with existing buildings in general mass, height, and setback, and in the treatment of architectural details, especially on building facades;

In the countryside, new buildings should be in harmony with the character of the surrounding landscape in terms of siting, scale, and materials;

Where development replaces a former use, that development should express the former use in some way. This may include one or more of the following:

> preserve and display fragments of former built features and landscaping;
>
> mark the traces of former locations, shapes, and circulation lines;
>
> display graphic and verbal description of former occupation; or
>
> reflect former architecture and plan in the new development; and

Where an undertaking will unavoidably destroy or significantly alter cultural property, actions should be taken to salvage information on the feature to be lost. Such actions could include, for example, archaeological exploration or excavations, and the recording of buildings or structures through measured drawings or photogrammetry.

A "Class" environmental assessment should describe the fundamental principles upon which mitigation measures concerning man-made heritage will be based as well as a method for decision making with respect to the identification and evaluation of the need for actions to prevent, change, mitigate, or remedy the adverse effects of particular projects within the class. Examples of the type of mitigative measures

> appropriate to projects within the class should also be given. Finally, the "Class" environmental assessment document should describe general procedures for monitoring man-made heritage concerns for the class activity as a whole, and indicate how reports required for each individual project within the class will contain a description of specific monitoring procedures.
>
> In the evaluation of the advantages and disadvantages of a "Specific" (or individual) undertaking and alternatives to the environment, an explanation should be made of how man-made heritage resources, as identified and evaluated as part of the environment, were ranked among other factors in deciding upon the desirability of the proposed change in the environment, and why any trade-offs involving either the destruction or the retention or the improvement of cultural property were considered necessary or appropriate. Moreover, it is particularly important in this evaluation that important conclusions, summary data, judgments, and recommendations be referenced to the appropriate background papers and record forms so that reviewers may independently investigate and evaluate the adequacy and validity of the non-technical presentation of the environmental assessment.
>
> For a "Class" undertaking, the method through which man-made heritage will be considered in carrying out the evaluation of alternatives and selecting the undertaking should be specified in the environmental assessment (Weiler 1980:13-14).

(As stated above, readers are referred to the full publication (Weiler 1980) for clarification of any of the points summarized above.)

6.4 Native Burials

In recent years the Native community has endeavoured to monitor and regulate the excavation and analysis of Native burials by archaeologists. Their actions have included attempts to increase public awareness about the sacredness of burial areas, to petition governmental agencies to produce policies covering these areas, and to arrest archaeologists in the process of excavating burials as a contravention of the Cemeteries Act. The results of such actions have been a heightened public awareness, proposed changes to the Cemeteries Act, and the implementation of guidelines for archaeologists concerning the discovery, excavation, and analysis of Native burials.

Today, all licences issued for archaeological fieldwork by the Ministry of Citizenship and Culture contain the following statement:

> "This licence does not permit the excavation of human burials unless the licencee has previously consulted with the Ministry of Citizenship and Culture."

If human burials are encountered by an archaeologist, he must notify the Regional Archaeologist of the Ministry of Citizenship and Culture. The Regional Archaeologist will then contact the local coroner (a provision of the Coroner's Act), and the local Cemeteries Branch (a provision of the Cemeteries Act). If it is ascertained that the burial is Native, the Regional Archaeologist will contact the local band chief or equivalent authority (a policy of the Archaeology and Heritage Planning Branch of the Ministry of Citizenship and Culture). If the local band chief agrees to allow the burial to be excavated, the Regional Archaeologist must obtain a certificate to exhume and transport from the Regional Medical Officer of Health (a provision of the Cemeteries Act). Exhumation is then undertaken by the Regional Archaeologist as licensed by the Ministry of Citizenship and Culture. If the burial is not jeopardized (i.e. impacted by proposed construction or development), then it will not be exhumed. In such case, or if the burial is ascertained to be non-Native, the burial is registered as an official cemetery. The cemetery then comes under the jurisdiction of the local Municipality, who assume responsiblity for its maintenance (provisions of the Cemeteries Act).

The above procedure is not yet the official policy of the Ministry of Citizenship and Culture, but is an interim working policy. The information was obtained from Mr. William A. Fox, Regional Archaeologist, Southwestern Region, Archaeology and Heritage Planning Branch, Ministry of Citizenship and Culture.

It should be noted that in recent years, local Native band councils have allowed the exhumation of Native burials with the stipulation that after the skeletal material has been analyzed it must be re-buried. Such re-burials have been undertaken in solemn ceremonies by the Native community.

7.0 CONCLUSIONS

Archaeological sites are ubiquitous: they can be and are located just about anywhere and everywhere. Maps 1 and 2 of this report indicate areas where large numbers of sites have been registered, where only a few sites have been registered, and where no sites are registered. This is not to say, however, that large numbers of sites, or even a few sites, are not located in those areas where no or few sites are now known. As indicated by sections 4.0, 5.0 and 11.0 of this report, the actual number of sites registered is a product of two inter-related factors: a) the known location and distribution of prehistoric groups for all time periods; and b) the amount of archaeological research conducted. The case studies in Section 11.0 in particular indicate that large numbers of sites can exist in areas that were once thought to have only a few sites. This shows the validity of conducting intensive archaeological survey in areas to be affected by development, while at the same time showing the inadequacy of present archaeological knowledge.

The first conclusion of this report is that there are only three broad areas of southern Ontario which, based on present knowledge, have no sites registered. These are indicated on Map 1 as those areas with large numbers of contiguous Borden Blocks with no sites registered. For clarification these can be roughly described as:

1. the area west of the Niagara Escarpment, south of Owen Sound, east of Kincardine and north of Listowel;
2. the area west, east and south of Algonquin Park, extending westward to Parry Sound, southward to Lakefield and eastward to but not including the Ottawa River;
3. the area east to southeast of Ottawa, southward to Winchester and eastward to but not including the Ottawa River.

All other areas of southern Ontario have some sites registered, or include small areas with no sites registered but which are bordered by areas with some sites registered.

Our second conclusion is that, given the nature of archaeological sites, intensive archaeological survey should be conducted in areas selected for a waste disposal facility before construction begins. Such a survey, involving multiple stages as outlined in Section 5.0, is a requirement of the Environmental Assessment Act and must be carried out by qualified archaeologists (see Section 6.0).

The final conclusion of this report concerns the nature of archaeological sites. While it is important to register all archaeological sites and to record the discovery of isolated artifacts (some of which have been assigned Borden numbers), not every site or find recorded can be avoided by a proposed waste disposal facility. Section 5.0 of this report outlined the procedures available to handle sites discovered through future archaeological survey. The presence of a site within a proposed waste disposal facility does not negate the possibility of placing the facility in that area. However, no general conclusions on this matter can be reached here since each archaeological site must be individually assessed in its own context. The only conclusion that can be reached at this time is that, should an archaeological site or series of sites be located in a proposed waste disposal facility area, there are a set of procedures available to deal with that site or those sites on an avoidance or mitigation basis (Section 5.0).

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9.0 APPENDIX A

Actual and Revised Site Densities by Borden Block

APPENDIX A: Actual Site Densities by Borden Block

Borden Block	Actual Density
AaHn	0
o	7
p	35
q	9
r	8
s	27
AbHk	0
l	11
m	0
n	0
o	0
p	1
q	0
r	3
s	4
AcHj	0
k	6
l	9
m	11
n	9
o	26
p	0
q	N/A
r	0
AdHa	1
b	0
c	8
d	8
e	6
f	4
g	3
h	16
i	16
j	14
k	3
l	2
m	29
n	6
o	18
p	0
AeHa	5
b	17
c	2
d	4
e	17

Borden Block	Actual Density
AeHf	36
g	54
h	38
i	15
j	2
k	1
l	4
m	0
n	0
o	0
AfHa	135
b	72
c	4
d	9
e	18
f	12
g	16
h	12
i	42
j	34
k	2
l	1
m	0
n	4
o	2
AgHa	44
b	49
c	27
d	10
e	1
f	1
g	0
h	58
i	0
j	0
k	16
l	1
m	2
n	6
o	2
AhHa	25
b	15
c	27
d	52
e	6
f	0

Borden Block	Actual Density
AhHg	2
h	9
i	0
j	1
k	89
l	26
m	4
AiHa	13
b	11
c	21
d	19
e	27
f	3
g	0
h	4
i	0
j	0
k	0
AjHa	5
b	4
c	0
d	0
e	6
f	3
g	0
h	0
i	10
j	3
k	0
AkHa	5
b	1
c	0
d	0
e	0
f	0
g	0
h	0
i	0
j	7
k	0

Borden Block	Actual Density
AlHa	0
b	0
c	0
d	0
e	0
f	0
g	0
h	0
i	0
j	0
k	0
AmHo	0
p	15
q	0
r	1
AnHp	5
q	8
r	0

Borden Block	Actual Density
AeGw	0
x	13
AfGr	4
s	1
t	25
u	49
v	68
w	87
x	49
AgGs	6
t	16
u	24
v	0
w	7
x	72
AhGs	5
t	0
u	3
v	2
w	34
x	24
AiGv	5
w	178
x	76
AjGt	0
u	14
v	27
w	40
x	38

Borden Block	Actual Density
AkGr	0
s	6
t	22
u	26
v	20
w	3
x	4
AlGf	4
g	16
h	32
i	7
j	0
k	0
l	0
m	4
n	10
o	28
p	36
q	45
r	11
s	109
t	150
u	13
v	16
w	20
x	2

Borden Block	Actual Density
BaHa	0
b	0
c	0
d	0
e	0
f	0
g	2
h	0
i	1
j	0
k	3
BbHa	17
b	7
c	0
d	0
e	0
f	0
g	0
h	0
i	0
j	18
BcHa	58
b	41
c	4
d	5
e	0
f	0
g	0
h	4
i	16
j	0
BdHa	5
b	3
c	8
d	6
e	0
f	0
g	0
h	2
i	2
BeHa	16
b	1
c	N/A
d	0
e	0
f	0
g	2
h	7

Borden Block	Actual Density
BfHa	5
b	0
f	0
g	0
h	0
i	1
BgHa	9
h	0
i	0
j	3
BhHa	18
b	0
h	0
i	1
j	16
k	5
BiHa	1
b	5
c	0
k	3
BjHa	0
b	0
c	3
d	0
j	3
k	2
BkHa	0
b	0
c	1
d	1
e	0
j	0
k	0
l	1
m	1
n	3
o	0
p	0
BlHa	1
b	0
c	0
d	0
e	0
f	1
g	1

Borden Block	Actual Density
BlHh	2
i	1
j	2
k	1
l	11
m	0
n	0
o	0
p	0
q	0
r	1
s	0
t	2
u	0

Borden Block	Actual Density
BaGc	1
d	0
e	0
f	16
g	15
h	16
i	19
j	13
k	2
l	0
m	4
n	64
o	30
p	30
q	10
r	22
s	24
t	0
u	14
v	7
w	13
x	4
BbGa	3
b	5
c	7
d	0
e	4
f	36
g	19
h	0
i	7
j	4
k	6
l	5
m	28
n	14
o	8
p	11
q	0
r	15
s	12
t	8
u	13
v	12
w	3
x	3
BcGa	3
b	7
c	1

Borden Block	Actual Density
BcGd	0
e	9
f	8
g	7
h	4
i	5
j	1
k	7
l	2
m	0
n	3
o	2
p	1
q	6
r	8
s	1
t	2
u	0
v	13
w	22
x	20
BdGa	32
b	0
c	5
d	6
e	2
f	6
g	6
h	2
i	3
j	2
k	2
l	0
m	10
n	0
o	0
p	1
q	3
r	10
s	2
t	0
u	7
v	14
w	31
x	16
BeGa	1
b	9
c	0
d	22

Borden Block	Actual Density
BeGe	0
f	0
g	0
h	1
i	0
j	0
k	0
l	0
m	3
n	0
o	0
p	0
q	2
r	0
s	6
t	1
u	0
v	5
w	18
x	31
BfGa	25
b	0
c	1
d	1
e	1
f	1
g	3
h	10
i	0
j	0
k	0
l	0
m	1
n	0
o	0
p	0
q	0
r	0
s	0
t	1
u	0
v	0
w	2
x	11
BgGa	1
b	0
c	0
d	0
e	0

Borden Block	Actual Density
BgGf	0
g	0
h	0
i	0
j	0
k	0
l	0
m	0
n	0
o	1
p	0
q	3
r	0
s	0
t	0
u	0
v	1
w	0
x	5
BhGa	0
b	0
c	1
d	1
e	1
f	5
g	0
h	6
i	3
j	2
k	0
l	0
m	0
n	0
o	1
p	1
q	2
r	0
s	0
t	0
u	0
v	0
w	0
x	2
BiGa	7
b	3
c	0
d	0
e	0
f	0

Borden Block	Actual Density
BiGg	0
h	0
i	0
j	3
k	1
l	0
m	0
n	2
o	16
p	3
q	1
r	11
s	0
t	0
u	2
v	0
w	0
x	0
BjGa	0
b	0
c	0
d	0
e	0
f	0
g	3
h	1
i	1
j	0
k	1
l	5
m	0
n	7
o	11
p	1
q	8
r	0
s	0
t	0
u	0
v	0
w	0
x	0
BkGe	0
f	1
g	14
h	0
i	0
j	0
k	1
l	0

Borden Block	Actual Density
BkGm	0
n	7
o	21
p	16
q	13
r	8
s	0
t	0
u	0
v	0
w	0
x	0
BlGe	0
f	3
g	0
h	0
i	1
j	7
k	19
l	3
m	9
n	4
o	11
p	40
q	0
r	5
s	8
t	0
u	0
v	0
w	0
x	0

Borden Block	Actual Density
BcFw	0
x	14
BdFv	2
w	2
x	1
BeFt	0
u	2
v	5
w	0
x	0
BfFr	1
s	1
t	3
u	1
v	4
w	0
x	0
BgFo	17
p	39
q	2
r	1
s	0
t	6
u	0
v	0
w	1
x	0

Borden Block	Actual Density
BhFo	1
p	0
q	1
r	0
s	2
t	0
u	0
v	0
w	5
x	1
BiFo	0
p	0
q	0
r	0
s	0
t	0
u	0
v	0
w	5
x	1
BjFo	2
p	1
q	0
r	0
s	2
t	0
u	1
v	0

10.0 APPENDIX B

Summary of High Density Areas

Explanation

The density distribution map (Map 1) indicates a total of 25 areas of high archaeological site density. These 25 areas are also indicated on a separate smaller map (Map 2). The following table lists those areas (A to Y), and a summary of the primary individuals and/or institutions who have conducted research in those areas. The reason that these 25 areas have a high density is directly related to the amount of research done in each area. Some of the areas listed below were chosen for the case studies in Section 5.0 (and Appendix C) of this report.

Map 2 also indicates two transects across Ontario, labelled I and II. These refer to the Niagara Escarpment Development Area and the CORTS Planning and Research Study Area, respectively, both of which are discussed in Section 5.0 (and Appendix C).

Key to High Density Areas (Maps 1 and 2)

Abbreviations: MCC = Minstry of Citizenship and Culture (formerly Ministry of Culture and Recreation)
MNR = Ministry of Natural Resources
MIA = Museum of Indian Archaeology (London)
NMM = National Museum of Man (Archaeological Survey of Canada)
ROM = Royal Ontario Museum

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Key	Region	Researchers
A	Kent and Essex Counties	University of Windsor; NMM
B	Point Pelee National Park	NMM
C	Lake St.Clair floodplain	MCC; MIA
D	Pinery Provincial Park (Case Study #1)	MIA; MCC; MNR
E	Caradoc Sand Plain	NMM; MIA; MCC; B.Deller; R.Williamson
F	City of London	MIA; NMM; MCC; J.Keron
G	St. Thomas Area	MIA; NMM; MCC; N. McWilliam
H	Norfolk Sand Plain/ Long Point	NMM; MCC; McMaster University; B. Fox
I	Grand River West (including Townsend Community Development Area - Case Study #2)	NMM; MCC; McMaster University; University of Waterloo; Wilfrid Laurier University; D.Stothers; C.Nixon
J	Grand River East	NMM; McMaster University; University of Toronto; MIA; D.Stothers; MCC
K	Metro Toronto-Burlington -Oakville (including Bronte Creek Provincial Park - Case Study #3)	University of Toronto; MCC; MIA; A. Roberts
L	Pickering (including New Toronto International Airport Case Study #4)	MIA; University of Toronto; MCC; North Pickering Survey
M	Durham/Rice Lake	Trent University; MCC; ROM; F. Ridley; A. Roberts

N	Prince Edward County (Part of CORTS Waterway)	NMM; MCC; J. Pendergast; K. Swayze
O	Bobs and Sharbot Lake	G. Watson
P	Rideau Lakes	G. Watson
Q	Charleston Lake Provincial Park (Case Study #5)	MCC
R	Cornwall/Lake St.Frances	NMM; W. kenyon; J. Pendergast
S	Petawawa River	B. Mitchell
T	Algonquin Park (Case Study #6)	University of Toronto
U	Shebishikong	NMM; MCC
V	Huronia (including Methodist Point Park Reserve Case Study #7)	MCC; ROM; MIA; MNR; Trent University; University of Toronto; G. Laidlaw; A.F. Hunter
W	Petunia	G.Garrd; NMM
X	Tobermory	NMM; MNR; S. McClellan
Y	Inverhuron	ROM; NMM; University of Toronto
I	Niagara Escarpment Development Area	MCC; various
II	CORTS Waterway (Canada-Ontario-Rideau-Trent-Severn Waterway)	MCC; various

11.0 APPENDIX C

Case Studies

Case Study 1: Pinery Provincial Park (Map 2:D)

1.1 Background

- archaeological survey of Park's heritage resources conducted by personnel from Historical Planning and Research Branch, Ministry of Culture and Recreation (formerly Historic Sites Branch, Ministry of Natural Resources) between 1972 and 1977 (Map 10).
- Park located in southwestern Ontario region
- inventory undertaken as part of Master Plan development for the Park

1.2 Physical Setting

- Park encompasses 2317 ha
- hydrology consists of the lower reaches of the Ausable River
- physiography includes the Huron Fringe containing immature shifting and mature stable sand dunes which form successive bands away from but paralleling the Lake Huron shoreline; soils are not conducive to agriculture (Chapman & Putnam 1973)
- dominant forest is an oak-pine complex; abundant aquatic and terrestrial floral and faunal resources typical of the Carolinian/Canadian Biotic Province transition zone are available (Cleland 1966)
- Kettle Point chert outcrops nearby

1.3 Principal Researchers

- Survey: Kenyon (1977, 1978); Stothers (1972)
- Excavation: Cutler (1969); Pihl (1981a)

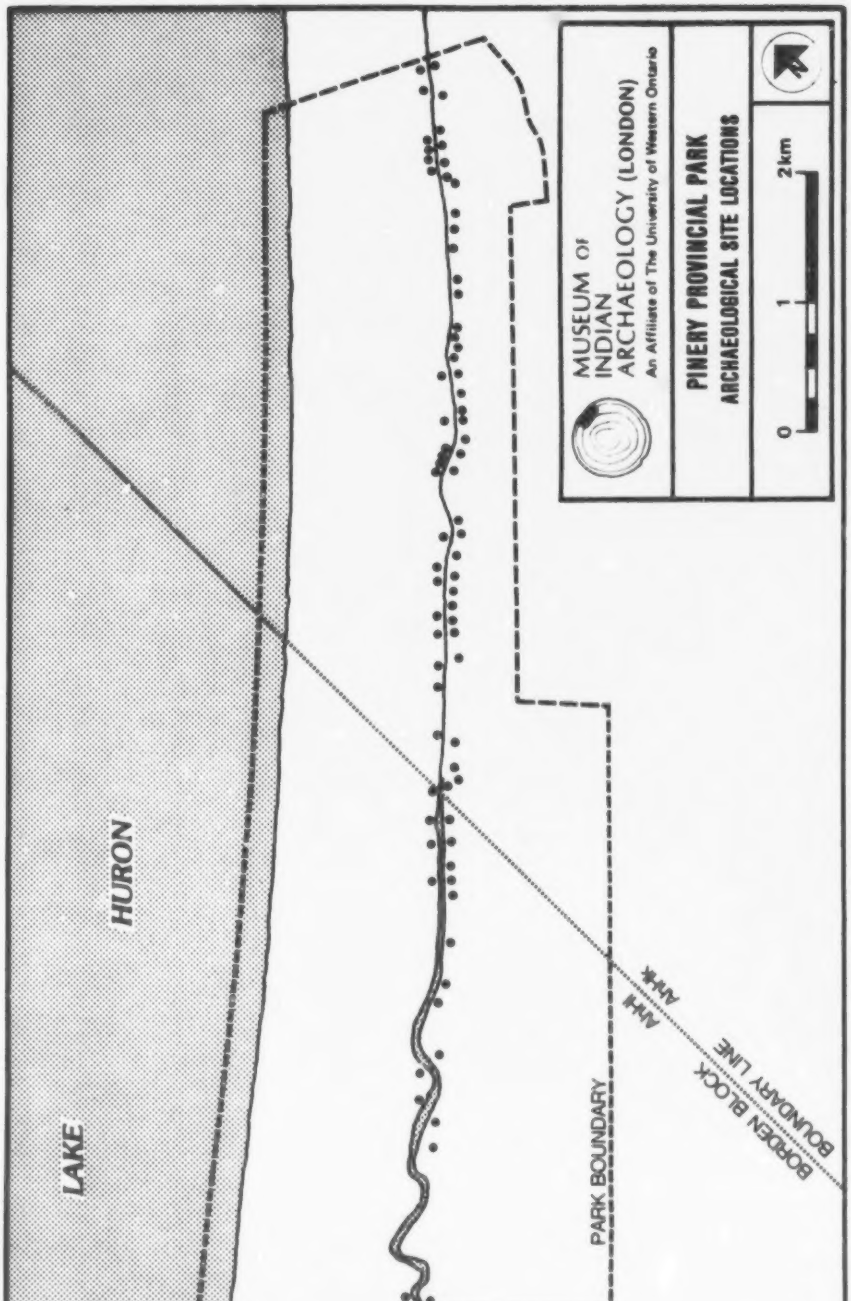
1.4 Cultural Chronology (sites per cultural period)

- Palaeo Indian: 0
- Archaic : 0
- Woodland : 58
- Historic : 4
- Indeterminate: 22

Total 84

1.5 Comments

- prior to the 1972 survey, less than five sites were known within the Park's boundaries
- the Park was intensively used during the Woodland period on a seasonal basis (probably for fishing); the sites also indicate that the processing of chert from nearby quarries was an important activity
- the entire stretch of the Ausable River (including a zone 70 meters on either side of it) has been designated an Heritage Resource Zone within the Master Plan (MNR 1977:50)


MUSEUM OF INDIAN ARCHAEOLOGY (LONDON)
An Affiliate of The University of Western Ontario
PINERY PROVINCIAL PARK
ARCHAEOLOGICAL SITE LOCATIONS
0
1
2km
LAKE
HURON
PARK BOUNDARY
BORDEN BLOCK BOUNDARY LINE
AhHk
AhHl
• Archaeological Site

(Adapted from Kenyon 1980)

Map 10

Case Study 2: Townsend Community Development Area (Map 2:I)

2.1 Background

- archaeological survey of project area conducted by personnel from Archaeological Research Associates (a private archaeological consulting firm) and from the Historical Planning and Research Branch, Mininstry of Culture and Recreation between 1976 and 1977 (Map 11)
- the project area is located in southwestern Ontario region
- the inventory was undertaken prior to proposed development by the Ontario Land Corporation

2.2 Physical Setting

- hydrology consists of portions of the Nanticoke, Catfish and Sandusk Creek drainages
- physiography is dominated by the Haldimand Clay Plain providing clay to clayey loam soils, and the Norfolk Sand Plain providing a sandy loam soil; the latter is more amenable to corn agriculture (Chapman & Putnam 1973)
- the forest cover ranges from an oak dominant to beech-maple to a pine dominated type; a full range of terrestrial and aquatic floral and faunal resources typical of the Carolinian Biotic Province (Cleland 1966) would have been available
- within the project area, outcroppings of Onondaga cherts are present

2.3 Principal Researchers

- Survey: Hamalainen (1977, nd); Knight (1976); Pearce (1979); Ramsden (1976)
- Excavation: Jamieson (1979)

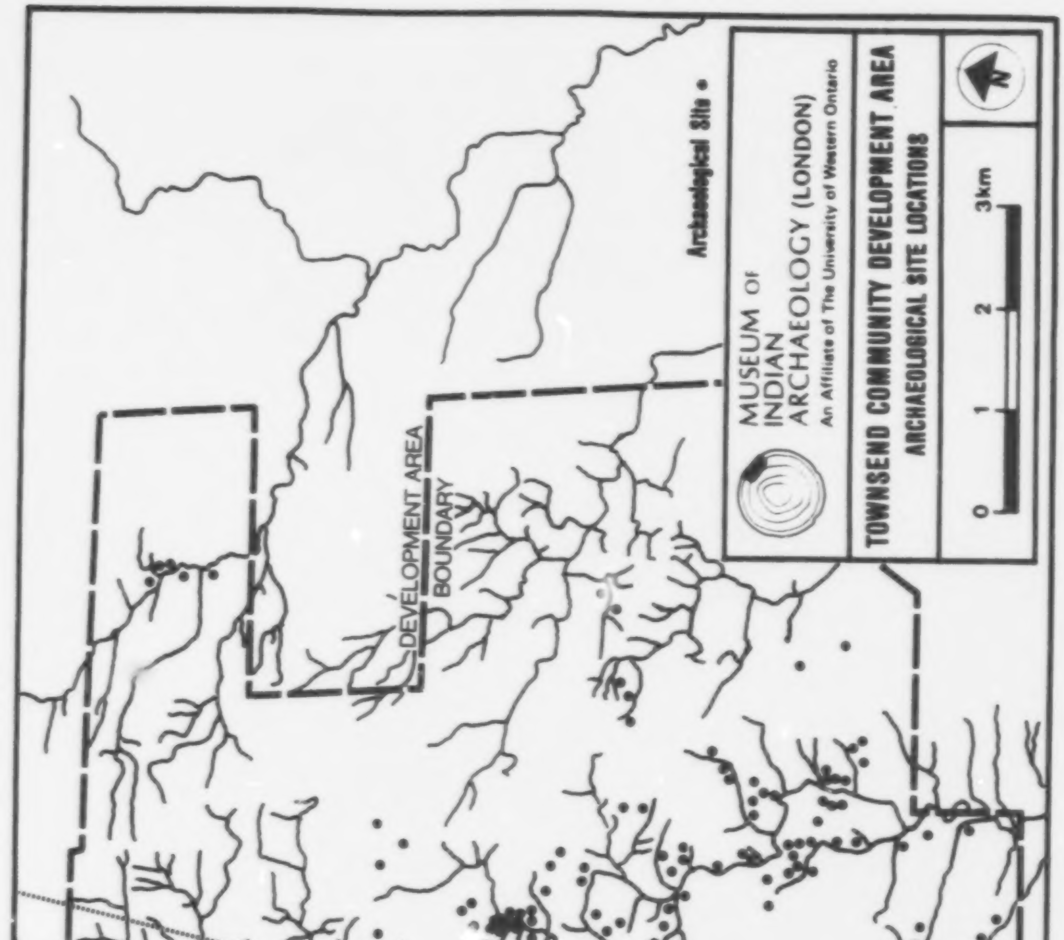
2.4 Cultural Chronology (sites per cultural period)

- Palaeo Indian : 1
- Archaic : 35
- Woodland : 21
- Historic : 13
- Multicomponent: 2
- Indeterminate: 282

Total 354

2.5 Comments

- prior to the surveys, only two sites were previously recorded
- project area was heavily exploited through time for its chert resources; dominant occupation was during the Archaic and later portions of the Woodland periods


MUSEUM OF INDIAN ARCHAEOLOGY (LONDON)
An Affiliate of The University of Western Ontario
TOWNSEND COMMUNITY DEVELOPMENT AREA
ARCHAEOLOGICAL SITE LOCATIONS
0
1
2
3km
N
Archaeological Site •
DEVELOPMENT AREA BOUNDARY
BORDEN BLOCK BOUNDARY LINE
AfHa
AfHb

(Adapted from Hamalainen nd)

Map 11

Case Study 3: Bronte Creek Provincial Park (Map 2:K)

3.1 Background

- archaeological survey of Park's heritage resources conducted by personnel from Historical Planning and Research Branch Ministry of Culture and Recreation, between 1972 and 1975 (Map 12)
- Park located in southcentral Ontario region
- inventory undertaken as part of Master Plan development for the Park

3.2 Physical Setting

- hydrology consists of the lower reaches of the Bronte Creek drainage
- Park straddles the South Slope with its loamy soils and the Iroquois Plain with its sandier soils; both areas are suitable for agriculture
- Park is characterized by a mixed deciduous forest capable of supporting a varied flora and fauna typical of the Carolinian/Canadian Biotic Province transition zone (Cleland 1966); aquatic resources would have been readily available as well

3.3 Principal Researchers

- Survey: Pihl (1981b); Swayze and Emerson (1973); Thomas *et al* (1975a, 1975b, 1975c)

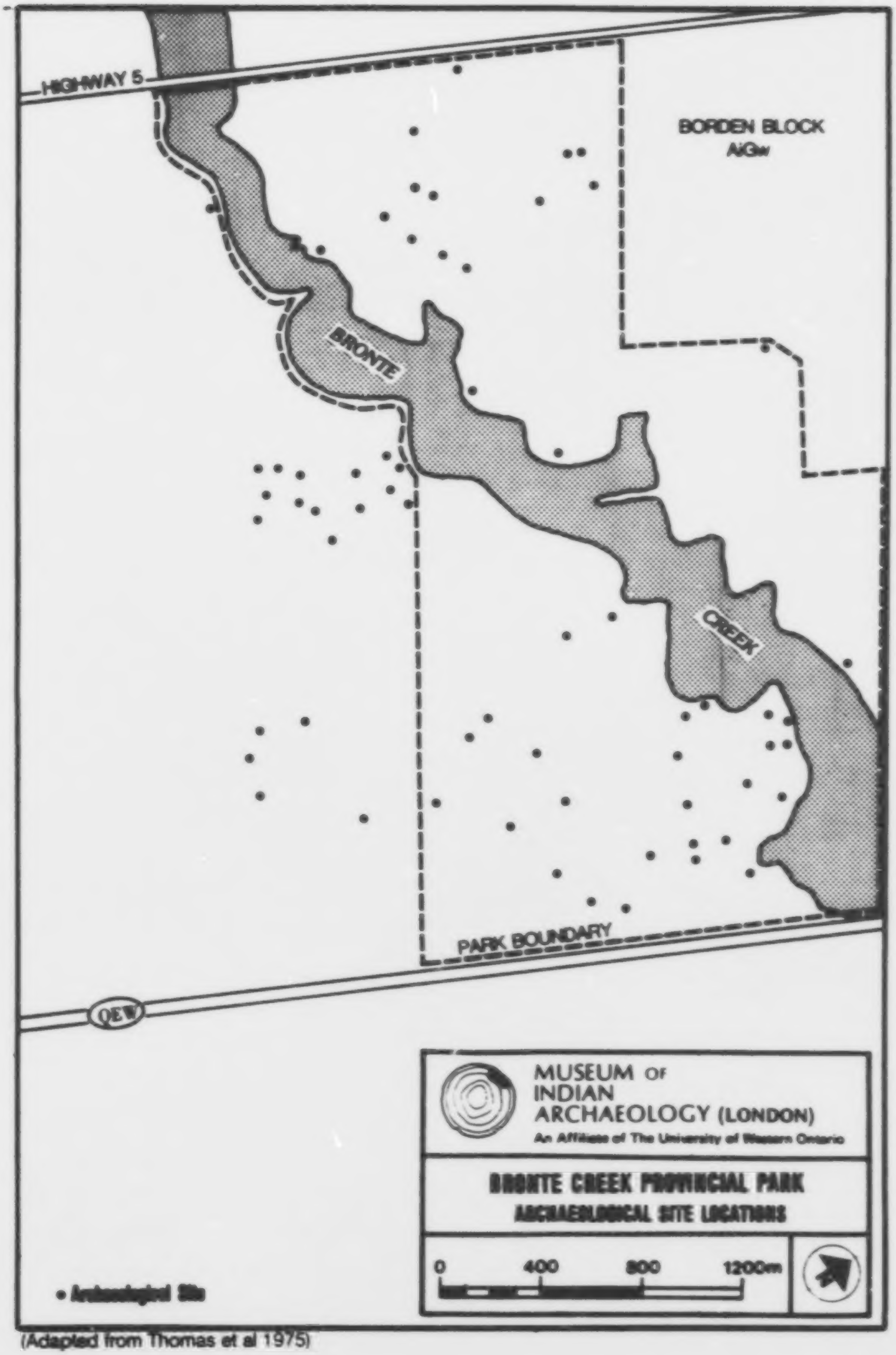
3.4 Cultural Chronology (sites per cultural period)

- Palaeo Indian : 0
- Archaic : 14
- Woodland : 3
- Historic : 0
- Multicomponent: 8
- Indeterminate : 28

Total 53

3.5 Comments

- prior to the surveys, no heritage resources were previously recorded
- Park was extensively occupied only during the Archaic period


HIGHWAY 5
BORDEN BLOCK
AiGw
BRONTE
CREEK
PARK BOUNDARY
QEW
MUSEUM OF
INDIAN
ARCHAEOLOGY (LONDON)
An Affiliate of The University of Western Ontario
BRONTE CREEK PROVINCIAL PARK
ARCHAEOLOGICAL SITE LOCATIONS
0
400
800
1200m
• Archaeological Site

(Adapted from Thomas et al 1975)

Map 12

Case Study 4: New Toronto International Airport (Map 2:L)

4.1 Background

- archaeological survey conducted by personnel of the Museum of Indian Archaeology (London), An Affiliate of The University of Western Ontario between 1976 and 1978
- Airport project area is located in southcentral Ontario region (Map 13)
- inventory undertaken as part of an assessment of heritage resources prior to airport development

4.2 Physical Setting

- airport project area encompasses nearly 7500 ha
- hydrology consists of portions of the Little Rouge and Duffin Creek drainages
- project area lies within the South Slope region and is dominated by loam to clay loam soils (Chapman & Putnam 1973)
- a maple-beech climax forest dominates although white pine stands occur throughout the project area; a wide range of terrestrial and aquatic flora and fauna would have been available in this Carolinian/Canadian Biotic transition zone (Cleland 1966)

4.3 Principal Researchers

- Survey: Finlayson et al (1977); Finlayson and Poulton (1979); Poulton (nd); Poulton and Finlayson (1978)
- Excavation: Donaldson (1962); Finlayson et al (1977); Finlayson and Poulton (1979); Hayden (1979); Latta (1973); Mayer (1979); Poulton (nd); Ramsden (1968); Timmins (1981); Tripp (1978); Williamson (1979)

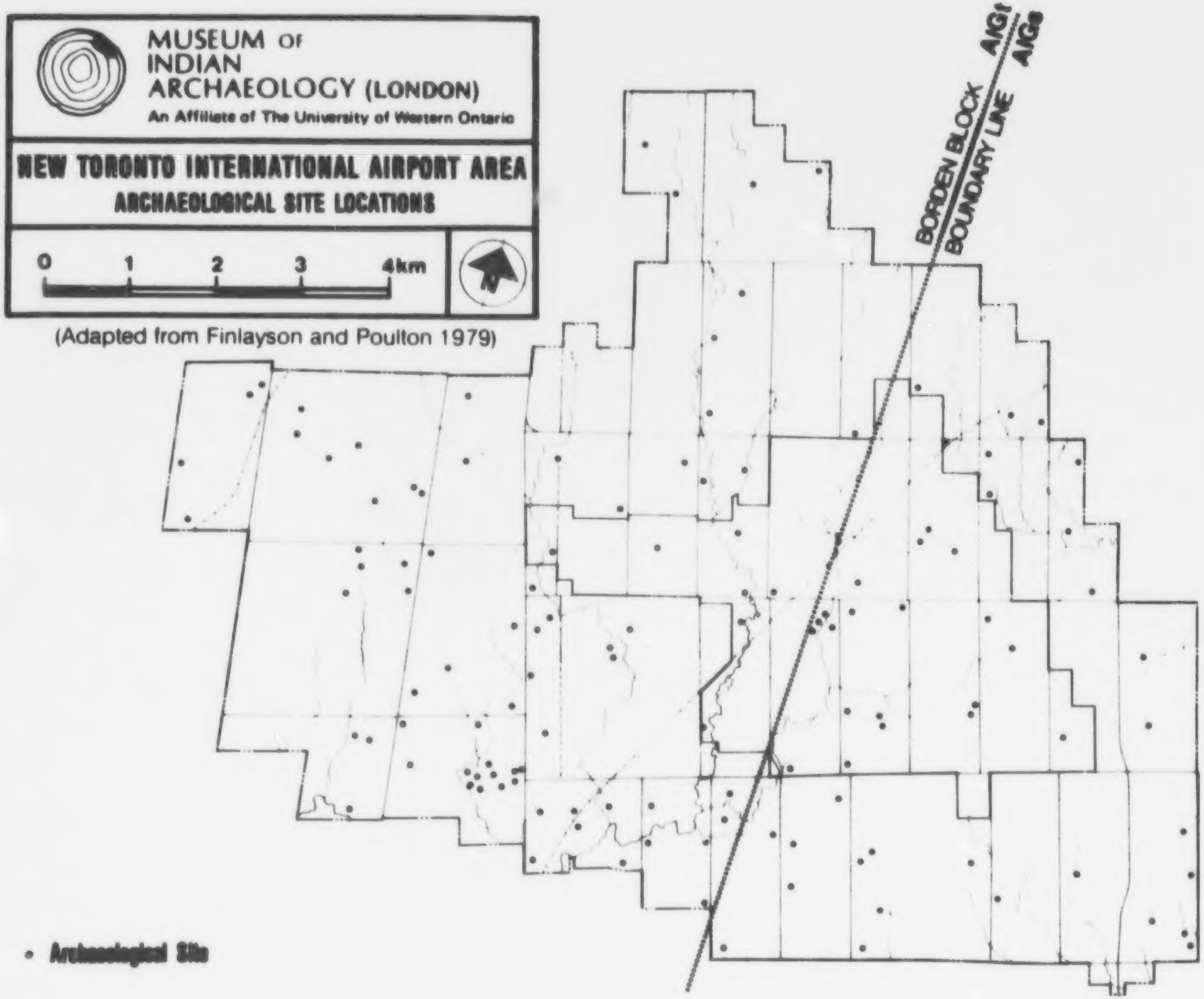
4.4 Cultural Chronology (sites per cultural period)

- Palaeo Indian : 1
- Archaic : 33
- Woodland : 20
- Historic : 0
- Multicomponent: 0
- Indeterminate : 78

Total 132

4.5 Comments

- prior to the surveys, only seven sites were known
- the project area was occupied from the Archaic through to the later phases of the Woodland periods, but was extensively used only in the latter


MUSEUM OF
INDIAN
ARCHAEOLOGY (LONDON)
An Affiliate of The University of Western Ontario
NEW TORONTO INTERNATIONAL AIRPORT AREA
ARCHAEOLOGICAL SITE LOCATIONS
0
1
2
3
4km
BORDEN BLOCK
BOUNDARY LINE
AlGt
AlGs
• Archaeological Site

(Adapted from Finlayson and Poulton 1979)

Map 13

Case Study 5: Charleston Lake Provincial Park (Map 2:Q)

5.1 Background

- archaeological survey of Park and vicinity's heritage resources conducted by personnel from Historical Planning and Research Branch, Ministry of Culture and Recreation between 1973 and 1976 (Map 14)
- Park located in southeastern Ontario region
- inventory undertaken as part of Master Plan development for the park

5.2 Physical Setting

- hydrology consists of a series of lakes (centred on Charleston Lake) which drain via the Gananoque River into the St. Lawrence River
- Park is situated on a portion of the Frontenac Axis (part of the Canadian Shield) which extends down to the St. Lawrence River; soils are coarsely-textured sandy loams (Hoffman et al 1964)
- a wide range of terrestrial and aquatic floral and faunal resources characteristic of the Carolinian/Canadian Biotic transition zone (Cleland 1966) would have been available

5.3 Principal Researchers

- Survey: Swayze (1975); Swayze and Bridges (1973)
- Excavation: Gordon (1970); Morrison (1975, 1977); Pelshea (1976); Swayze (1975, 1976b)

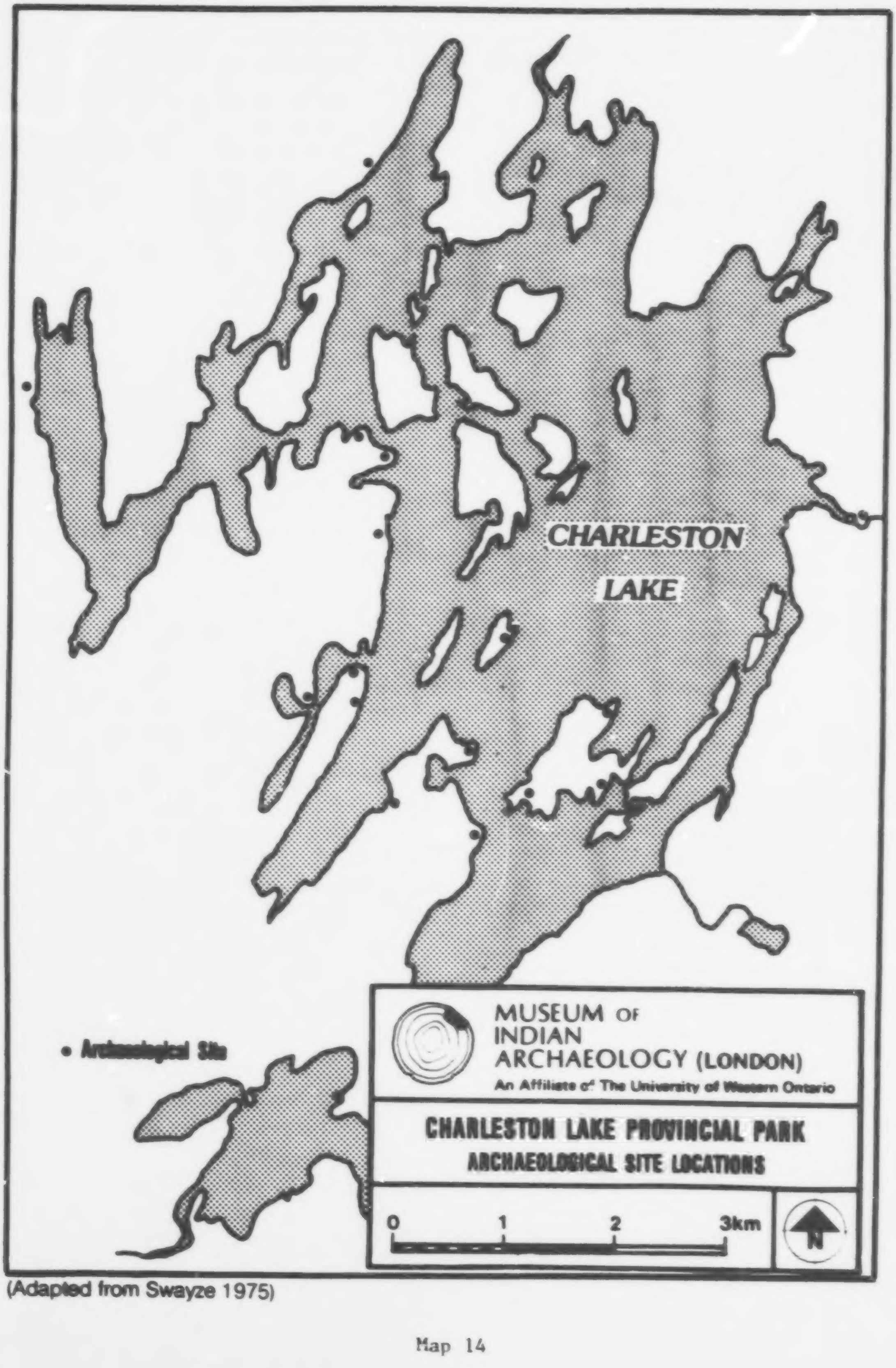
5.4 Cultural Chronology (sites per cultural period)

- Palaeo Indian : 0
- Archaic : 1
- Woodland : 6
- Historic : 0
- Multicomponent: 6
- Indeterminate : 12

Total 25

5.5 Comments

- prior to the surveys, only one site was registered
- the Park and vicinity was extensively used during the Woodland period on a seasonal basis, probably for fishing; many of the rockshelter sites were re-used over a thousand year span of time


CHARLESTON
LAKE
• Archaeological Site
MUSEUM OF
INDIAN
ARCHAEOLOGY (LONDON)
An Affiliate of The University of Western Ontario
CHARLESTON LAKE PROVINCIAL PARK
ARCHAEOLOGICAL SITE LOCATIONS
0
1
2
3km
N

(Adapted from Swayze 1975)

Map 14

Case Study 6: Algonquin Provincial Park (Map 2:T)

6.1 Background

- archaeological survey of Park's heritage resources conducted by personnel from the Department of Anthropology, University of Toronto from 1970 to 1971 (Map 15)
- Park located in southeastern Ontario region
- inventory conducted as part of the Master Plan development of the Park

6.2 Physical Setting

- Park encompasses 7536.9 sq.km.
- hydrology consists of portions of five major drainage systems: Ausable du Fond, Muskoka, Petawawa, Bonnechere and Madawaska Rivers; hundreds of lakes reside within the Park
- Park sits within the Pre-Cambrian Shield; soils are coarse-textured, thin, and infertile
- a mixed and varied flora and fauna characteristic of the Canadian Biotic Province would have been available

6.3 Principal Researchers

- Survey: Hurley *et al* (1970, 1972); Mitchell (1969); Mitchell *et al* (1970)
- Excavation: Clarke (1955a, 1955b, 1956, 1958); Kidd (1948); Mitchell *et al* (1966); Noble (1968)

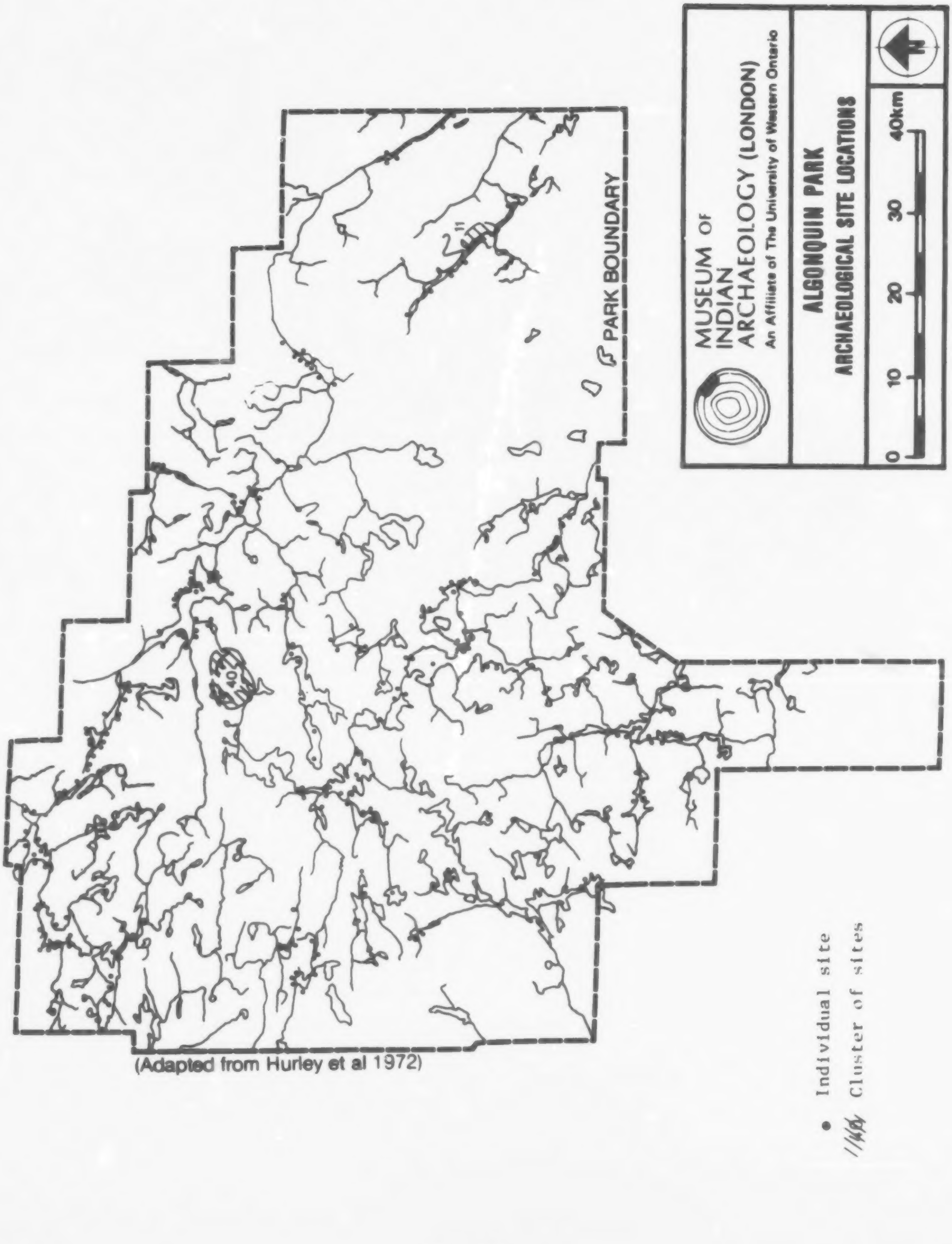
6.4 Cultural Chronology (sites per cultural period)

- Palaeo Indian : 0
- Archaic : 6
- Woodland : 8
- Historic : 1
- Multicomponent: 38
- Indeterminate : 228

Total 281

6.5 Comments

- prior to the surveys in 1970 and 1971, only 17 sites were recorded
- majority of the sites indicate sparse prehistoric occupation of the Park, although quite a few Historic sites are present (both single and multicomponent sites) suggesting extensive use during the logging era
- the river systems were not major transportation routes through time


MUSEUM OF INDIAN ARCHAEOLOGY (LONDON)
An Affiliate of The University of Western Ontario
ALGONQUIN PARK
ARCHAEOLOGICAL SITE LOCATIONS
0
10
20
30
40km
PARK BOUNDARY
40
11
• Individual site
//// Cluster of sites

(Adapted from Hurley et al 1972)

Map 15

Case Study 7: Methodist Point Park Reserve (Map 2:V)

7.1 Background

- archaeological survey of Reserve's heritage resources conducted by personnel from the Historic Sites Branch, Ministry of Natural Resources between 1972 and 1973 (Map 16)
- Reserve is located in the southcentral Ontario region
- inventory conducted as part of Master Plan development for the reserve

7.2 Physical Setting

- Reserve encompasses approximately 2225 ha
- situated on Penetang Peninsula off Georgian Bay; a beachline of glacial Lake Nipissing crosses the reserve
- hydrology consists of a series of kettle lakes as well as water from Georgian Bay
- the soils range from sandy loam to loamy sand, but wetland is distributed throughout the Reserve
- vegetation consists of a young hardwood forest; a wide variety of aquatic and terrestrial flora and fauna characteristic of the Carolinian/Canadian Biotic transition zone (Cleland 1966) are available.

7.3 Principal Researchers

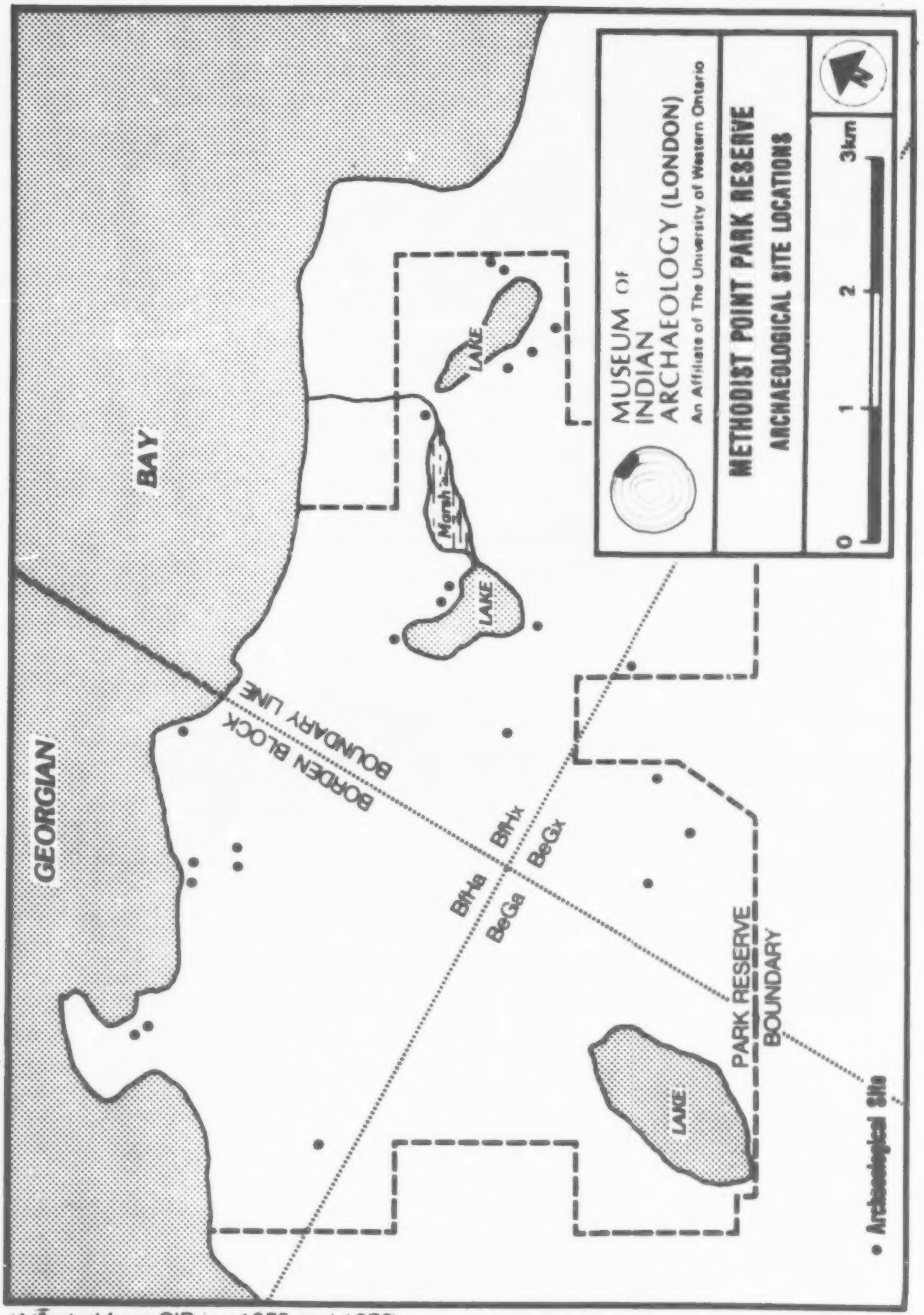
- Survey: Gwynne (1971); O'Brien (1976); Ridley (1966); Kenyon (1970)
- Excavation: Gwynne (1967, 1970); O'Brien (1976); Smith (1979)

7.4 Cultural Chronology (sites per cultural period)

- Palaeo Indian :	0
- Archaic :	1
- Woodland :	10
- Historic :	0
- Multicomponent:	3
- Indeterminate :	5
Total	19

7.5 Comments

- prior to the 1972 and 1973 surveys, only three sites were recorded
- the Reserve was extensively occupied by Woodland peoples between A.D. 1400-1650


GEORGIAN
BAY
BORDEN BLOCK BOUNDARY LINE
BfHa
BfHx
BeGa
BeGx
PARK RESERVE BOUNDARY
LAKE
LAKE
LAKE
Marsh
MUSEUM OF INDIAN ARCHAEOLOGY (LONDON)
An Affiliate of The University of Western Ontario
METHODIST POINT PARK RESERVE
ARCHAEOLOGICAL SITE LOCATIONS
0
1
2
3km
• Archaeological Site

(Adapted from O'Brien 1975 and 1976)

Map 16

Case Study 8: CORTS Planning and Research Study Area (Map 2:II)

8.1 Background

- archaeological survey of heritage resources located within confines of the Canadian-Ontario-Rideau-Trent-Severn (CORTS) study area conducted by personnel from the Historical Planning and Research Branch, Ministry of Culture and Recreation between 1976 and 1977 (Map 17)
- corridor transects southern Ontario from Ottawa down to the St. Lawrence River - Prince Edward County and then proceeds west up the Trent into Lake Simcoe and Georgian Bay
- located in southeastern and southcentral Ontario regions

8.2 Physcial Setting

- the major drainages involved are the Rideau, Trent and Severn Rivers
- a diverse range of physiographic regions occur in the study area ranging from the Ottawa Valley Clay Plains, Smith Falls Limestone Plains, Leeds Knobs and Flats to the east, the Napanee Plain, Dummer Morains, Peterborough Drumlin Fields and Oak Ridges Moraine in the central portion, and finally the Schomberg Clay Plains, Simcoe Uplands and Lowlands and the Carden Plain to the west (Chapman and Putnam 1973); soils vary tremendously in texture, but agricultural potential for aboriginal purposes is generally high, especially for the region including the Upper Trent and Lake Simcoe/Georgian Bay (Chapman and Putnam 1973)

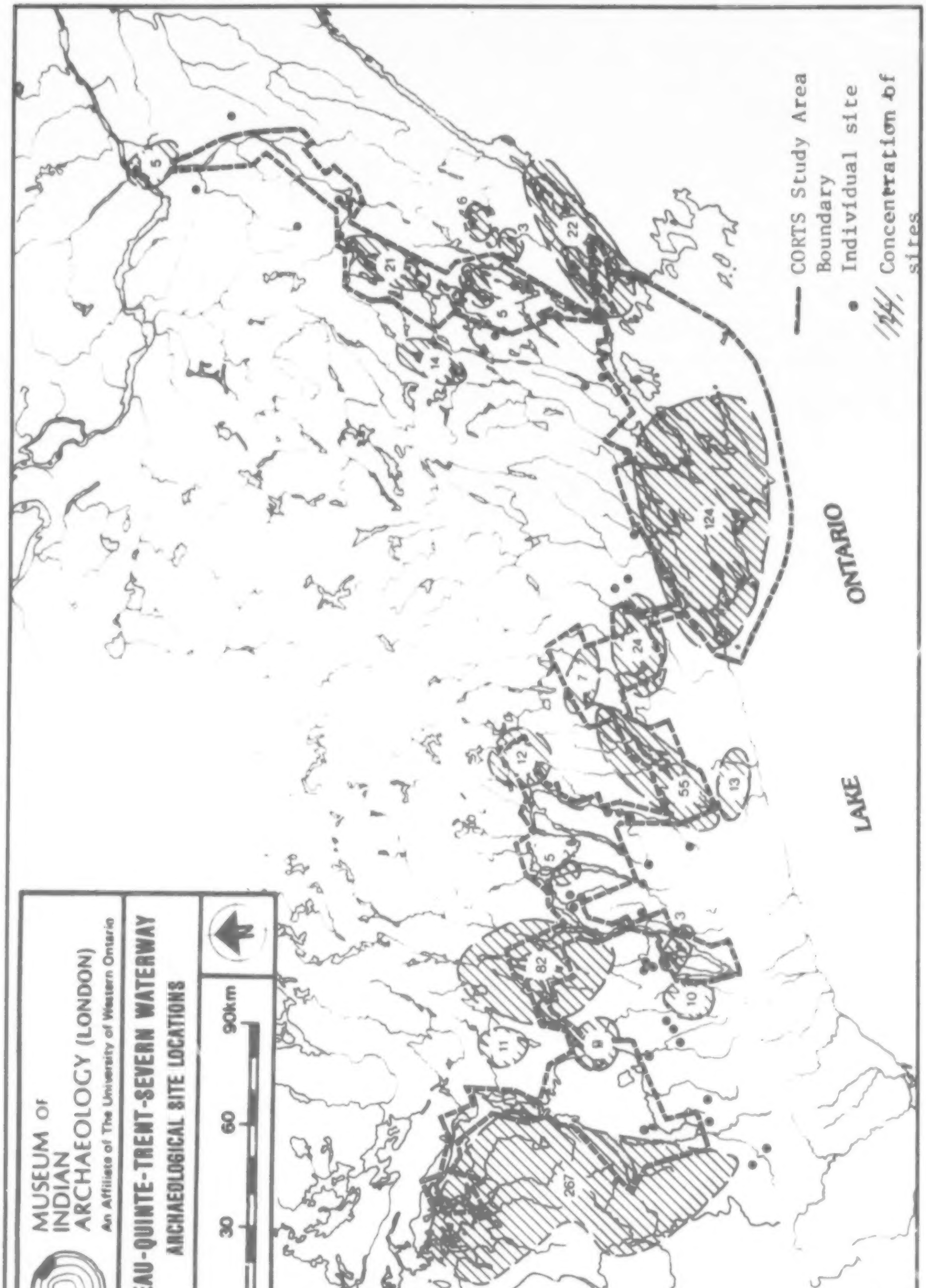
8.3 Principal Researchers (selected references only)

- Survey: Johnston (1968a); Richardson (1968); Ridley (1966); Ritchie (1949); Swayze (1976b)
- Excavation: Emerson (1966); Hurley and Heidenreich (1969); Johnston (1968b, 1976); Pearce (1977); Pendergast (1964); Ramsden (1978); Ritchie (1949); Tyyska (1969); Watson (1980)

8.4 Cultural Chronology (approximate number of sites per period)

- Palaeo Indian : 23
- Archaic : 113
- Woodland : 316
- Historic : 35
- Indeterminate : 410

Total 897


MUSEUM OF
INDIAN
ARCHAEOLOGY (LONDON)
An Affiliate of The University of Western Ontario
RIDEAU-QUINTE-TRENT-SEVERN WATERWAY
ARCHAEOLOGICAL SITE LOCATIONS
0
30
60
90km
LAKE
ONTARIO
267
82
11
9
10
3
5
55
13
12
7
24
124
14
6
21
3
6
22
5
CORTS Study Area Boundary
• Individual site
▨ Concentration of sites

(Adapted from CORTS Study, M.C.R. 1981)

Map 17

NOTE

These totals are estimates only and do not reflect accurately the number of multicomponent sites known within the CORTS study region.

8.5 Comments

- the Rideau Lakes region is important from ca. 4000 BC-AD 1300 but especially during the Woodland period from 500 BC-AD 1300.
- Prince Edward County peninsula has a very intensive occupation during the Woodland period from 500 BC-AD 1550; it also was important during the Archaic period
- the Trent River - Rice Lake region is renowned for its Woodland occupation from ca. 200 BC-AD 500 but recent work on the Archaic period 4000-3000 BC has revealed numerous sites
- the upper Trent watershed contains a recently documented Terminal Woodland occupation of significance; research has linked it to the Huron homeland around Georgian Bay
- the region between Lake Simcoe and Georgian Bay is the historic homeland for the Huron Confederacy although the region also has a cultural prehistory stretching back many thousands of years.

Case Study 9: Prince Edward County (Map 2:N)

9.1 Background

- archaeological survey of all possible site locations (registered or otherwise) conducted by personnel from the Historical Planning and Research Branch, Ministry Culture and Recreation in 1976; museum and university files and private collectors were all contacted for information (Map 18)
- study area located in southeastern Ontario Region
- inventory conducted as part of the CORTS Planning and Research Study

9.2 Physical Setting

- area encompasses 1010 square km
- physiography consists mostly of a limestone plain with small sections of clay and sand plains in the north and central sections of the peninsula, respectively; soils are mostly medium-coarsely textured loams although clay soils are distributed in the northern area and muck/wetland soils are scattered throughout
- hydrology includes minor tributaries along the margins of the peninsula, but the main water sources are the Bay of Quinte and Lake Ontario
- the many embayments along the shoreline provide sheltered areas for habitation
- dominant forest is a beech-maple type; extensive tracts of marsh/wetlands occur throughout the peninsula; a diverse assortment of aquatic (marshland) and terrestrial flora and fauna are available characteristic of the Carolinian/Canadian Biotic transition zone.

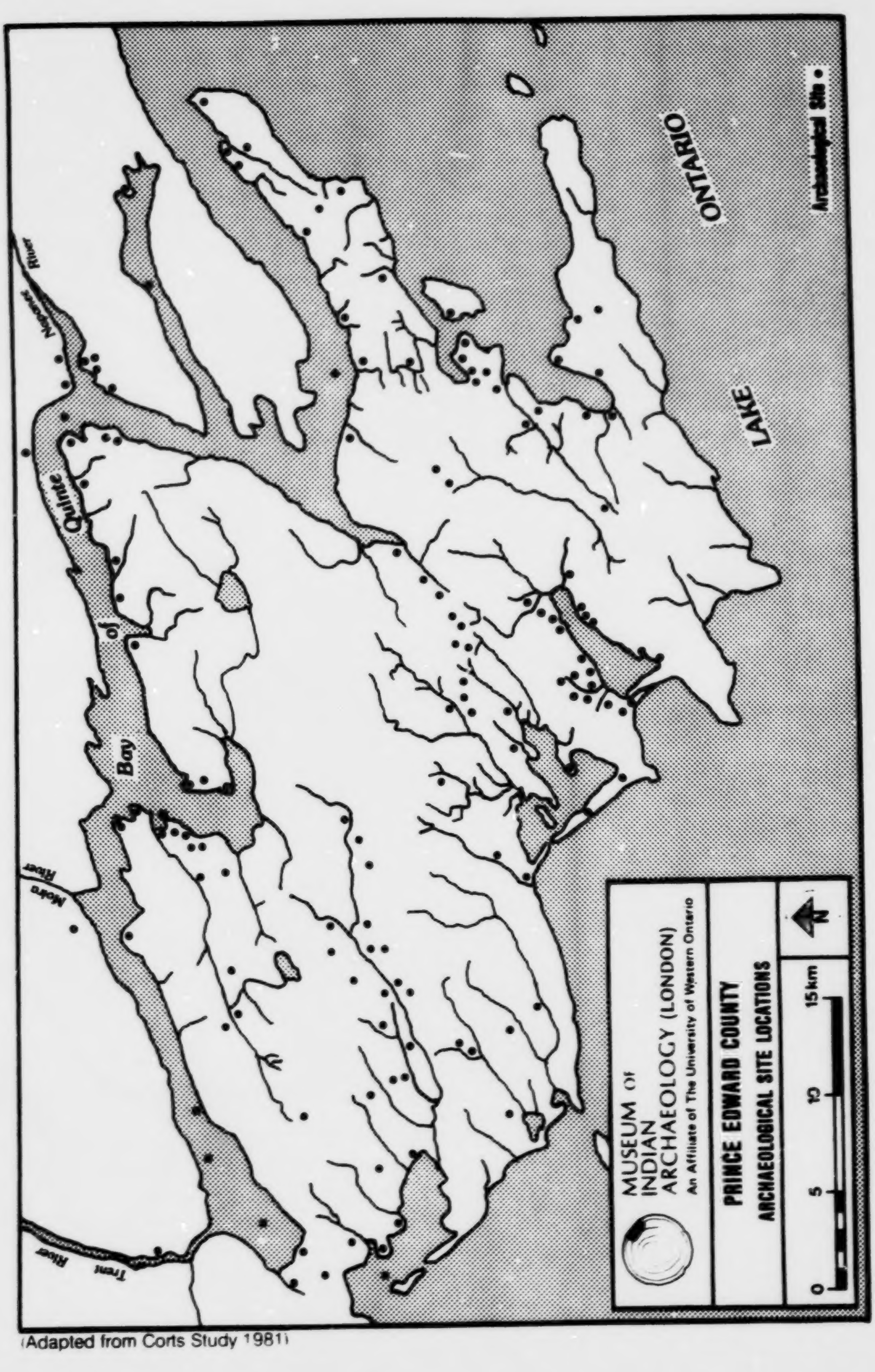
9.3 Principal Reserachers

- Survey: Ritchie (1949); Swayze (1976b)
- Excavation: Emerson (1966); Pendergast (1964)

9.4 Cultural Chronology (sites per cultural period)

- Palaeo Indian : 0
- Archaic : 20
- Woodland : 29
- Historic : 4
- Multicomponent : 10
- Indeterminate : 61

Total 124


MUSEUM OF
INDIAN
ARCHAEOLOGY (LONDON)
An Affiliate of The University of Western Ontario
PRINCE EDWARD COUNTY
ARCHAEOLOGICAL SITE LOCATIONS
0
5
10
15km
N
Archaeological Site •
LAKE
ONTARIO
Bay
of
Quinte
Napanee River
Moira River
Trent River

(Adapted from Corts Study 1981)

Map 18

9.5 Comments

- extensive occupation of region from Archaic through Late Woodland
- sites cluster around the sheltered embayments which comprise a rich marsh habitat

Case Study 10: Niagara Escarpment Development Area (Map 2:I)

10.1 Background

- archaeological study of heritage resources located within the boundaries of the Niagara Escarpment Development Area conducted by personnel from the Historical Planning and Research Branch, Ministry of Culture and Recreation between 1974 and 1976
- corridor transects southern Ontario from the tip of the Bruce Peninsula south, along the Niagara Escarpment, past Georgian Bay (Collingwood), Hamilton, and around the southern shore of Lake Ontario (Map 19)

10.2 Physical Setting

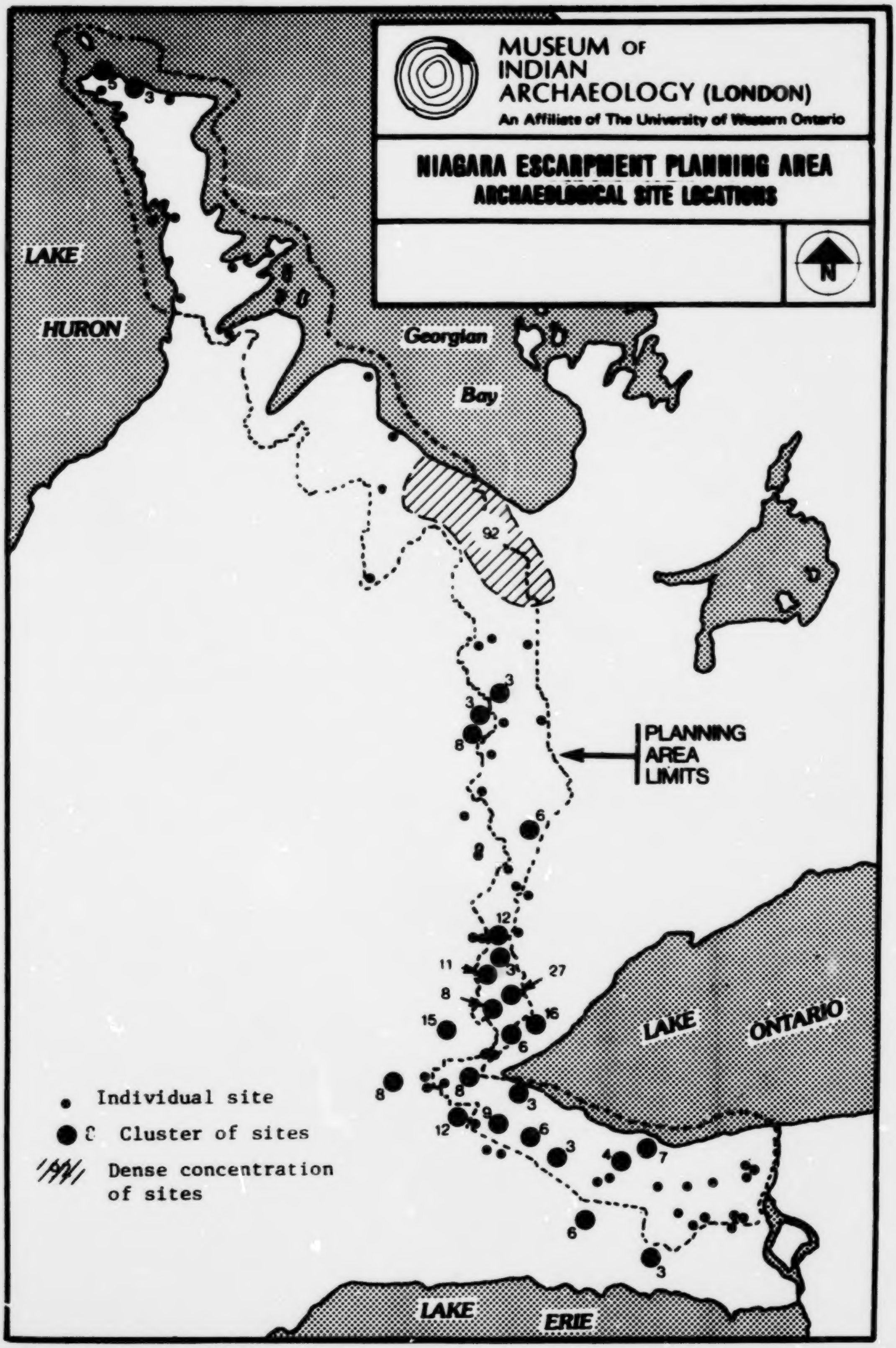
- corridor is defined principally by the presence of the Niagara Escarpment
- numerous water systems traverse the Escarpment through pre-glacial notches; in addition many drainage systems have their headwaters on the Escarpment
- the physiography of the Escarpment is highly variable ranging from the Canadian Shield up north, a variety of morainic and drumlin deposits in the centre, to the Haldimand Clay plain on the south (Chapman and Putnam 1973); soils vary as well from shallow bedrock soils up north, medium to coarsely textured soils formed from till deposits, to the clays characteristic of the south end of the Escarpment (Hoffman et al 1964)
- forests range from the coniferous northern forests to the deciduous southern forests and the range and type of floral and faunal resources varies accordingly from those characteristic of the Canadian Biotic Province to those of the Carolinian Biotic Province (Cleland 1966)

10.3 Principal Researchers (selected references only)

- Survey: Ellis (1979); Garrad (1974); Kenyon (1972); Noble (1978); Pelshea et al (1973); Storck (1971); Stothers (1976); Swayze (1972); White (1972)
- Excavation: Garrad (1974); Lennox (1981); Storck (1979); Wintemberg (1946); Wright, JV (1981); Wright, M (1981)

10.4 Cultural Chronology (approximate number of sites per period)

- Palaeo Indian	:	3
- Archaic	:	67
- Woodland	:	186
- Historic	:	1
- Multicomponent	:	16
- Indeterminate	:	83
Total		356

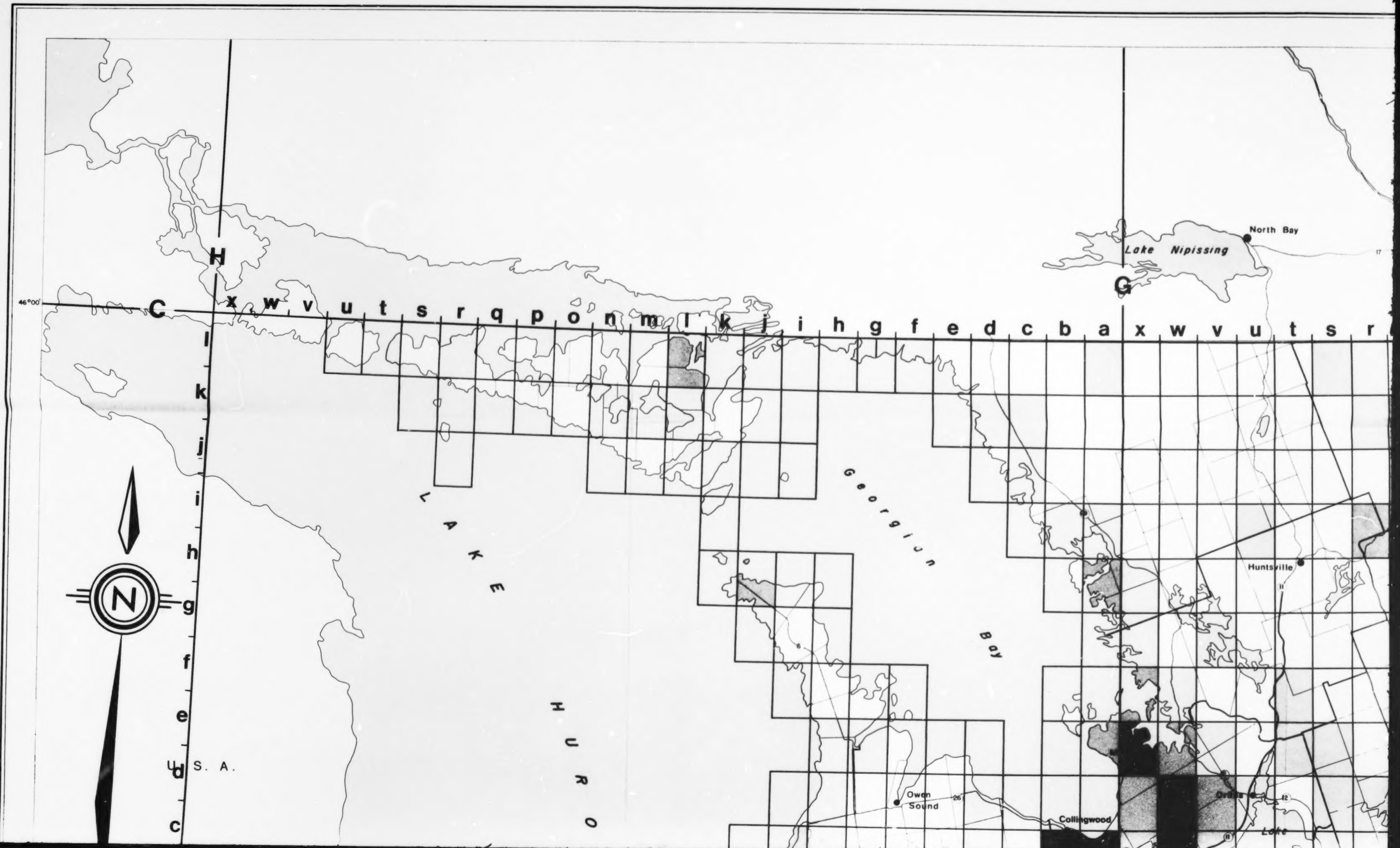

MUSEUM OF INDIAN ARCHAEOLOGY (LONDON)
An Affiliate of The University of Western Ontario
NIAGARA ESCARPMENT PLANNING AREA
ARCHAEOLOGICAL SITE LOCATIONS
N
LAKE HURON
Georgian Bay
LAKE ONTARIO
LAKE ERIE
PLANNING AREA LIMITS
92
Individual site
Cluster of sites
Dense concentration of sites

(Compiled from MCC nd)

Map 19

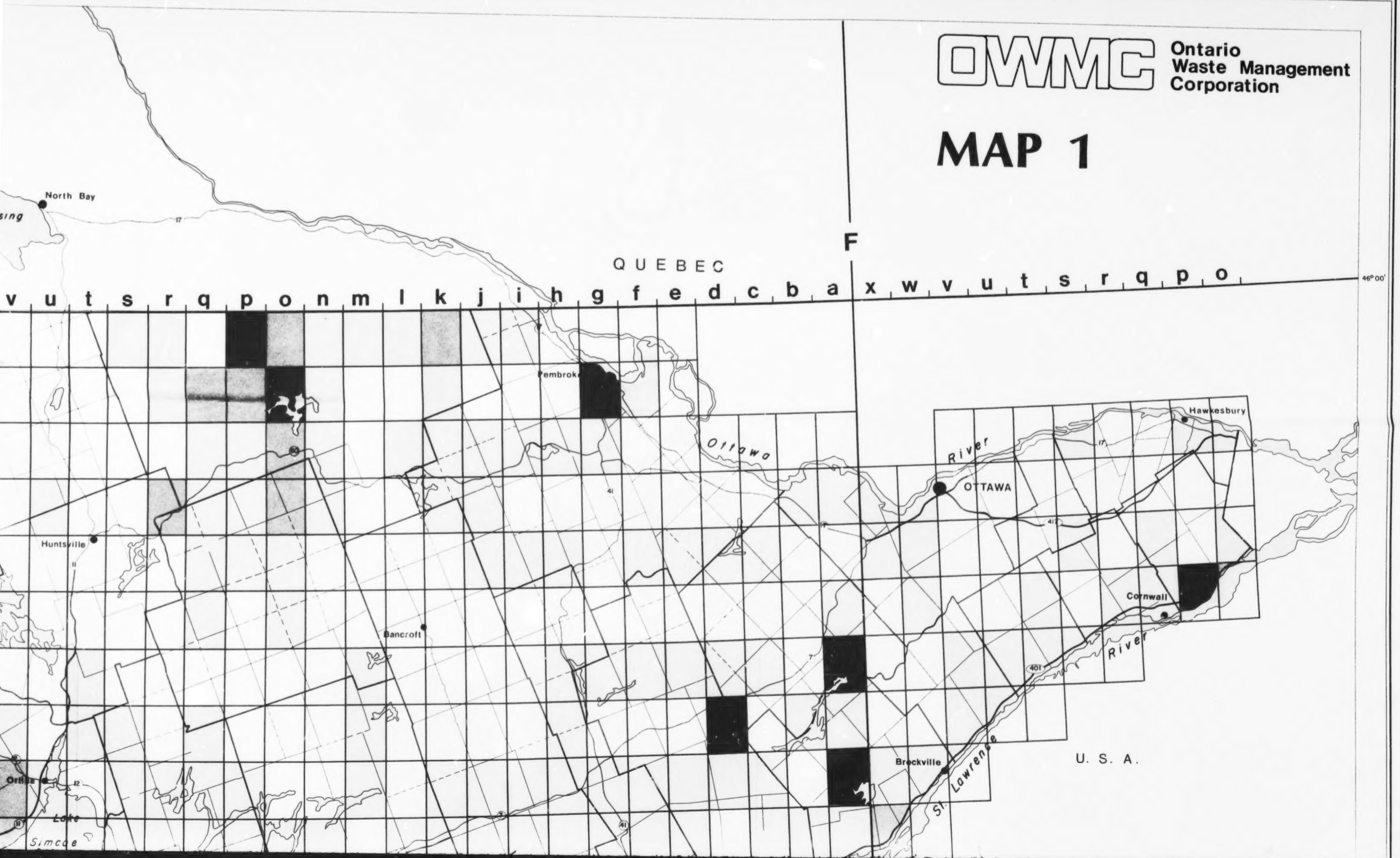
10.5 Comments

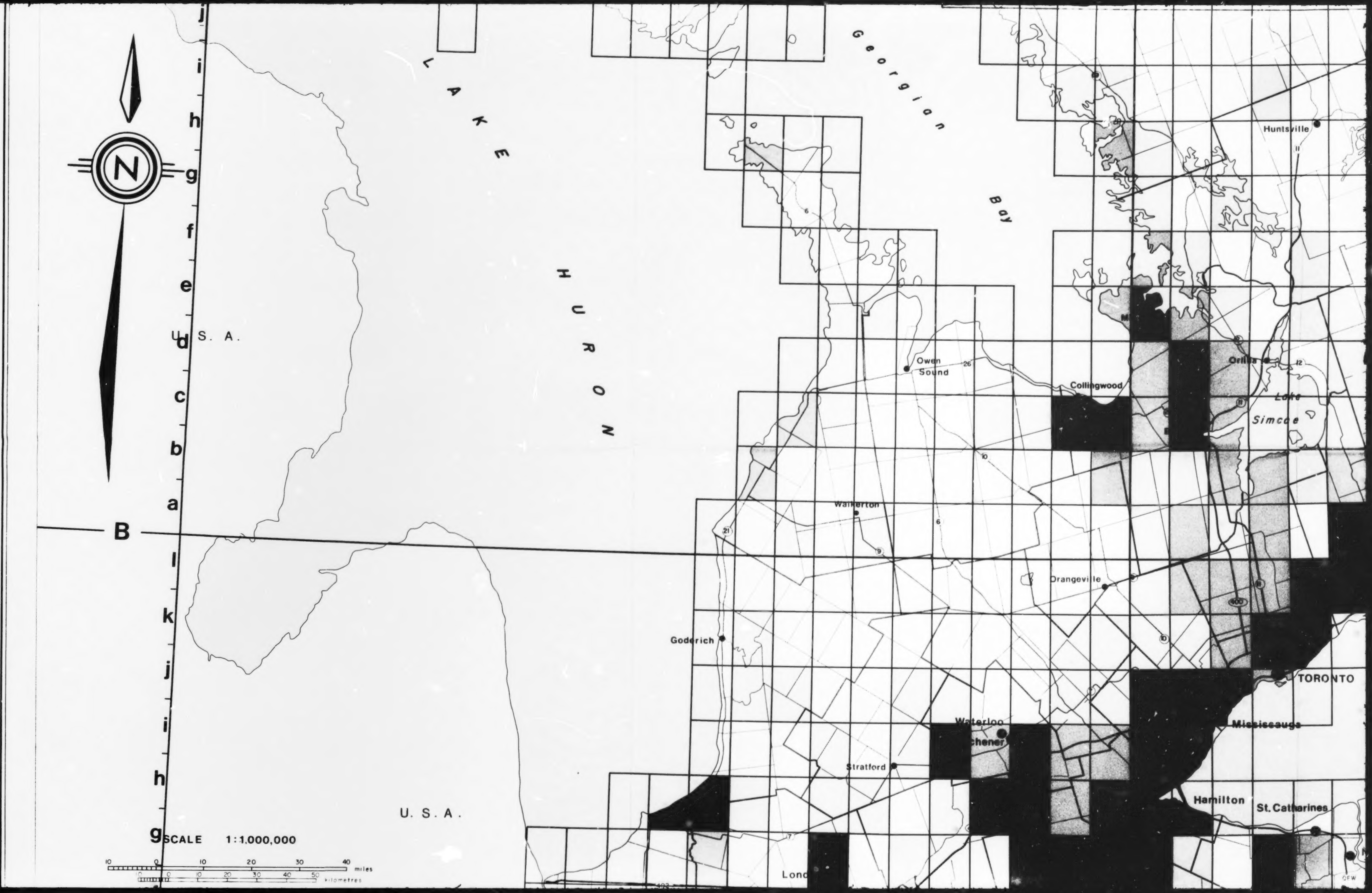
- two areas stand out as having areas of extremely high aboriginal site density: around the Collingwood area where the Historic Petun Indians were located; and around the Hamilton-Milton-Niagara area where the long development of the Historic Neutral Indians occurred
- centred on the Bronte Gap are numerous Palaeo Indian sites (findspots); but around Collingwood, many large Palaeo Indian sites have recently been investigated

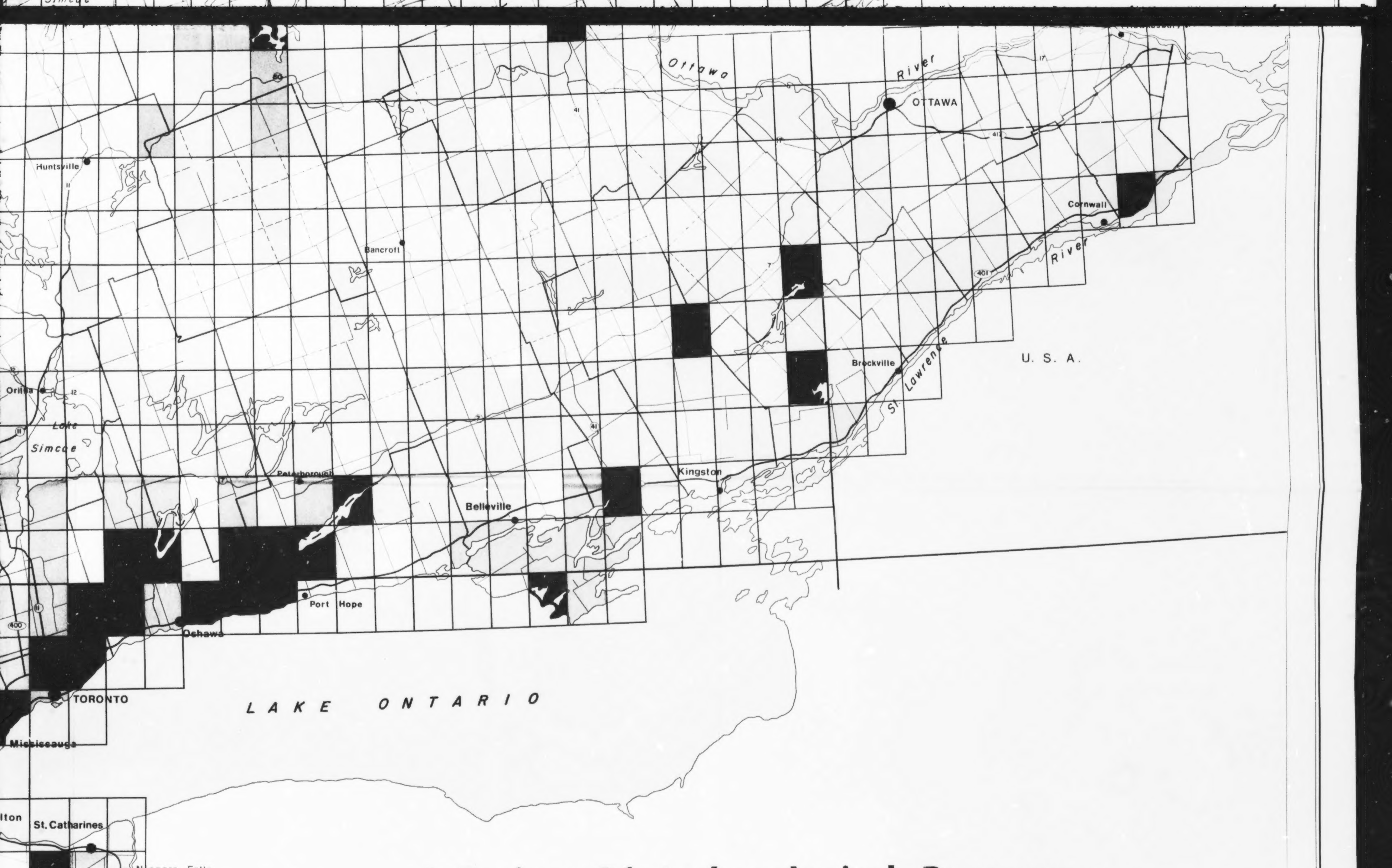

H
G
C
46°00'
x w v u t s r q p o n m l k j i h g f e d c b a x w v u t s r
l
k
j
i
h
g
f
e
d
c
N
U. S. A.
LAKE HURON
Georgian Bay
Lake Nipissing
North Bay
17
Huntsville
11
6
Owen Sound
26
Collingwood
Orillia
12
11
Lake

Ontario Waste Management Corporation

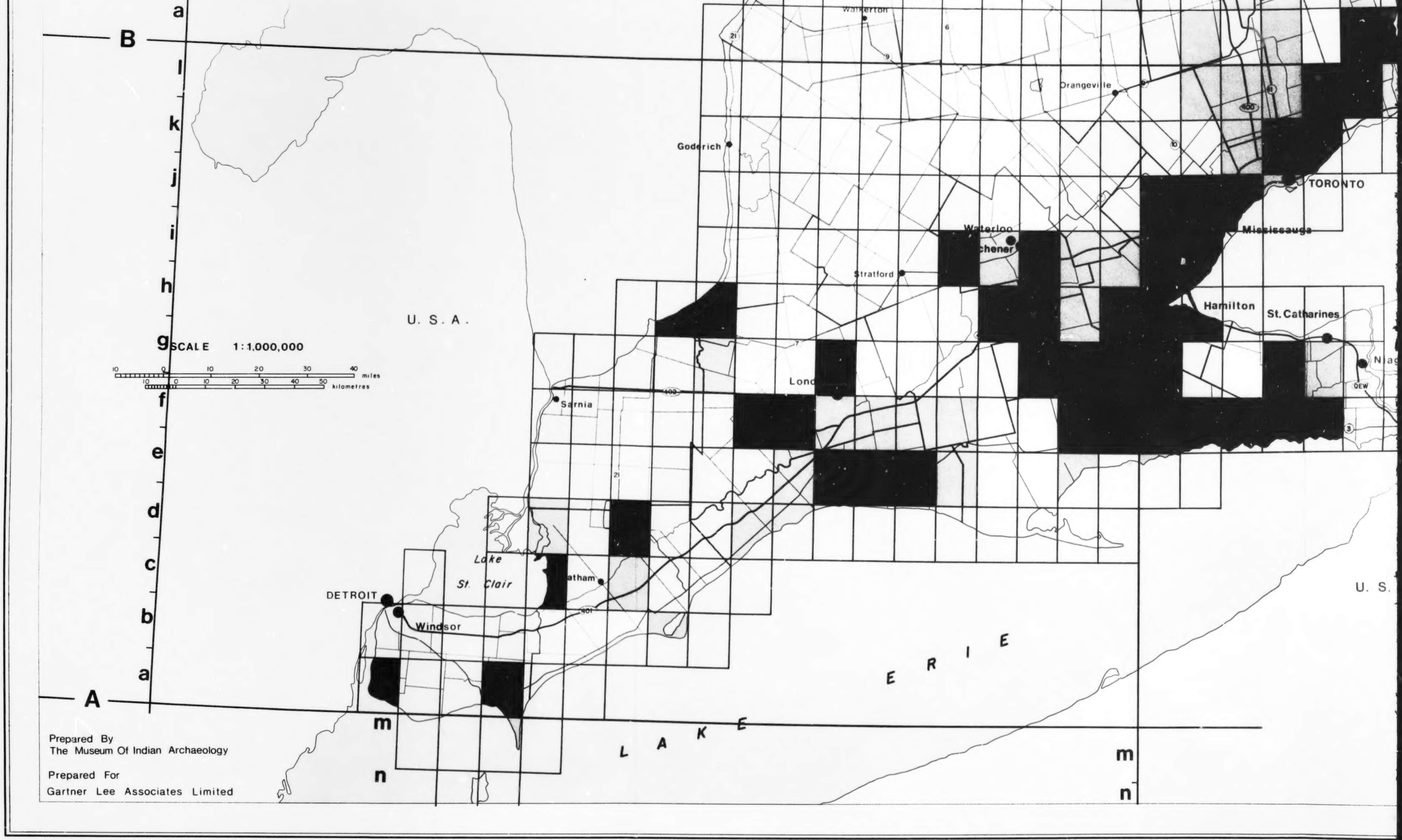
MAP 1


North Bay
sing
17
QUEBEC
F
v u t s r q p o n m l k j i h g f e d c b a x w v u t s r q p o
46°00'
Pembroke
Ottawa
River
OTTAWA
Hawkesbury
17
417
Huntsville
11
Bancroft
41
7
Cornwall
River
401
Brockville
St. Lawrence
U. S. A.
Orillia
12
Lake
Simcoe


L A K E H U R O N
G e o r g i a n B a y
U. S. A.
U. S. A.
N
B
j
i
h
g
f
e
d
c
b
a
l
k
j
i
h
g
Huntsville
Owen Sound
Collingwood
Orillia
Lake Simcoe
Walkerton
Orangeville
Goderich
Waterloo
Kitchener
Stratford
TORONTO
Mississauga
Hamilton
St. Catharines
Lond
SCALE 1:1,000,000
miles
kilometres
10
0
10
20
30
40
50
400
QEW
6
26
10
21
9
11
12
7


Simcoe
60
Ottawa River
17
OTTAWA
41
417
Huntsville
11
Bancroft
Cornwall
River
401
7
Brockville
St. Lawrence
U. S. A.
12
Orillia
Lake Simcoe
11
41
Peterborough
7
Kingston
Belleville
Port Hope
11
400
Oshawa
TORONTO
LAKE ONTARIO
Mississauga
lton
St. Catharines
Niagara Falls

A Review Of Archaeological Resources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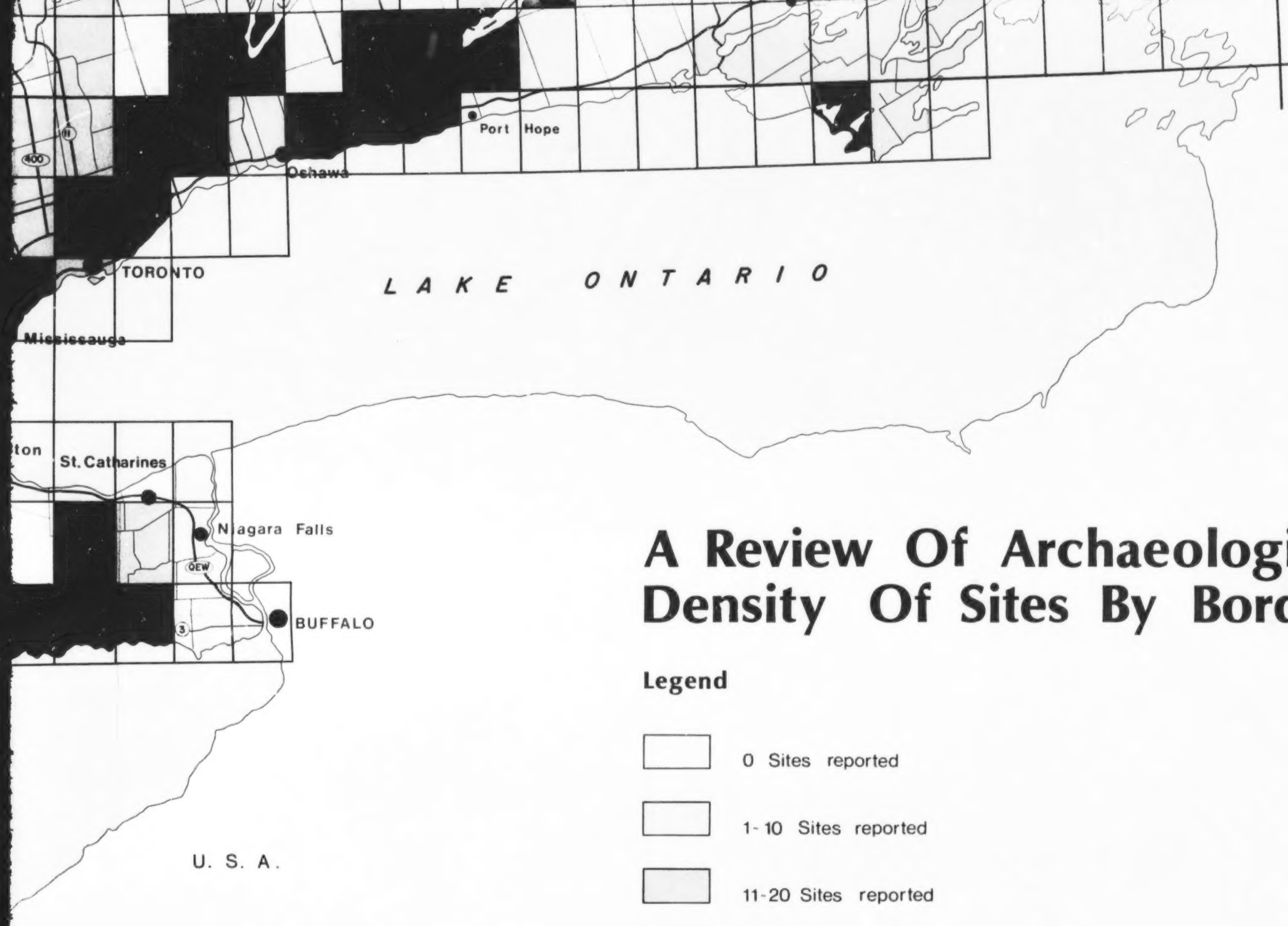
Prepared By
The Museum Of Indian Archaeology

Prepared For
Gartner Lee Associates Limited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A Review Of Archaeological Resources - Density Of Sites By Borden Block

Legend

☐ 0 Sites reported

☐ 1-10 Sites reported

▨ 11-20 Sites reported

■ 21-50 Sites reported

■ 51 plus Sites reported

Volume

1

OWMC

Ontario Waste Management Corporation

FINAL REPORT

PRIMARY ENVIRONMENTAL INFORMATION
PART 4
CLIMATOLOGY - VOLUME I

Gartner Lee Associates Limited
Engineering Geologists, Hydrogeologists, Biologists,
Environmental Consultants

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Toronto - Buttonville Airport ▪ Markham, Ontario ▪ L3P 3J9 ▪ 416-477-8400
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PRIMARY ENVIRONMENTAL INFORMATION
PART 4
CLIMATOLOGY - VOLUME I

PREPARED BY:

S.C. BARTON
M. DOBSON
ONTARIO RESEARCH FOUNDATION

FOR

GARTNER LEE ASSOCIATES LIMITED

PROJECT NO. 82-1007

SEPTEMBER, 1982

Gartner Lee Associates Limited

Consulting
Engineering
Geologists and
Hydrogeologists

Toronto-Buttonville Airport ■ Markham, Ontario ■ L3P 3J9 ■ 416-477-8400
Telex - 06-986278

September 2, 1982.

Mr. E.H. Schmidt, P.Eng.,
Project Director,
Ontario Waste Management Corporation,
60 Bloor Street West,
Suite 707,
Toronto, Ontario,
M4W 1A1.

Dear Mr. Schmidt:

Re: Final Report - Preliminary Environmental Information, Part 4 - Climatology (GLAL 82-1007)

We are pleased to transmit to the Corporation the Climatology Report prepared by the Department of Environmental Chemistry of the Ontario Research Foundation. This report is accompanied by a separate technical appendix (Volume II). The study provides an overview of air pollution potential for Southern Ontario with respect to the siting of waste management facilities with air emissions.

The Ontario Research Foundation and ourselves are pleased to be of service.

Yours very truly,

GARTNER LEE ASSOCIATES LIMITED

Grant Anderson

E.G. Anderson, P.Eng.,
Project Director.

DSO:jcm

FINAL REPORT
PRIMARY ENVIRONMENTAL INFORMATION
PART 4
CLIMATOLOGY

S.C. Barton
M. Dobson
Department of Environmental Chemistry

September 2, 1982

ONTARIO RESEARCH
FOUNDATION

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EXECUTIVE SUMMARY

ABSTRACT

The objective of this study was to provide information which can be used to identify optimum regions for hazardous waste management facilities in Southern Ontario. Climatological, meteorological and topographical features of Southern Ontario have been used to define, on a relative basis, areas of high air pollution potential that should be seriously considered in the siting of such facilities.

Relatively consistent climatological and meteorological conditions are found to prevail throughout Southern Ontario. Variations in the dispersive capacity of the atmosphere in this area are concluded to be primarily a function of the interaction of specific local landforms and atmospheric phenomena. Three types of zones have been identified where dispersion conditions are complicated by effects such as lake breezes, topographic features and the urban heat island. It is concluded that the region can generally expect to experience an adequate dispersal of pollutants emitted from a waste management facility in all regions, with the exception of:

- any lands within approximately 2 km of the shoreline of the Great Lakes
- the region bordered by the Niagara Escarpment and Lake Ontario, and
- major urban centres.

The occurrence of abnormally high pollution levels can be expected to occur, and have been recorded in heavily industrialized regions, within 2 km of lake shores because of the recirculation or entrapment of local emissions by lake breeze effects. The lake breeze effect may, in fact, extend up to 30 km inland, but only under unusual circumstances, and thus sites within a zone of 30 km from the shoreline of the Great Lakes, the St. Lawrence River and the Ottawa River may, on

occasion, be subject to slightly more complex dispersion patterns than would be encountered further inland. The region bordered by the Niagara Escarpment and Lake Ontario experiences the trapping of pollutants emitted below the level of the escarpment. The lowering of mixing heights due to lake breeze circulations further serves to retard dispersion inland past the escarpment. The urban heat island promotes increased mixing of the atmosphere immediately above a city. During the day, this increases the dispersal capacity of the atmosphere. However, nocturnal stable atmospheres experienced in the surrounding rural regions will ensure that a stable "lid" exists above the influence of the heated urban region. Pollutants emitted into these low mixing layers at night will result in high ground level concentrations, especially at the city fringes.

Compared with the regions under the influence of these effects, the remainder of Southern Ontario experiences relatively good dispersion conditions most of the time. The air pollution potential indices used in this study are the frequency of stable atmospheric conditions (ground-based inversions) and ventilation coefficients (a product of the mean maximum afternoon mixing height and mixed layer wind speed). It is important to note that the word 'potential' means conditions that can develop, if all the criteria are met (high levels of emissions being the first and main criteria). Annually, stable conditions which are conducive to poor dispersion are experienced approximately 27 percent of the time in Southern Ontario. Mid-day ventilation coefficients for the region indicate that a potential for high air pollution on an annual basis exists approximately 55 percent of the time due to a combination of low mixing heights and wind speeds. The persistence of constant wind conditions, however, is less than six hours in most cases, resulting in the dispersion of accumulated pollutants before significant levels are reached.

INTRODUCTION

This Report discusses meteorological dispersion conditions in Southern Ontario, as they pertain to air pollution potential. The objective of this study was to provide information which can be used in conjunction with the results of other ongoing site selection studies to identify optimum locations for hazardous waste management facilities in Southern Ontario. Climatological parameters which have been assessed include air temperatures, frost, precipitation, fog, and sunshine hours. Meteorological parameters studied were surface winds, atmospheric stability, mixing heights, mixing layer winds and ventilation coefficients. The effects of specific local features such as topography, lake breeze circulations and urban 'heat islands', were addressed in conjunction with these atmospheric parameters to provide an overall assessment of the potential for poor dispersion conditions to occur. A Technical Appendix, containing the more detailed figures and tables, accompanies this Report, under separate cover, Volume II.

BACKGROUND

Air pollution potential can be defined as a meteorological condition which, given the existence of emissions, would be conducive to the development of poor air quality. The parameters which have been used in this study as meteorological indices of air pollution potential are:

- frequency of stable conditions (ground-based inversions)
- surface wind properties, and
- ventilation coefficients (product of mixing layer heights and mixing layer wind strengths).

Stable conditions retard the dispersion of pollutants, creating high ground level concentrations when the plume eventually encounters an unstable portion of the atmosphere (for example, slightly inland from a shoreline during the summer). Pollutants emitted under unstable conditions will dilute sufficiently in most cases, and result in lower ground level concentrations. Mixing layer heights reflect the upper limit of the unstable conditions and mixing of the pollutants emitted into the lower atmosphere. Prevailing wind conditions determine downwind receptors and dispersal patterns under various stability conditions.

Several specific features of relevance to air pollution potential in Southern Ontario are:

- The Great Lakes, and to a lesser extent, the St. Lawrence River and the Ottawa River. Lake breeze effects can create poor dispersion conditions to within approximately 2 km of the shoreline, when advected stable air from over the water encounters unstable air inland, dispersing pollutants to ground level (fumigation). Under unusual conditions this zone may extend up to 30 km inland.
- The urban heat island. Urban centers formulate their own nocturnal mixing heights (due to stored up energy in the day) with the surrounding stable rural air, trapping pollutants within the city.
- Topographical features, the most notable being the Niagara Escarpment. Pollutants can be trapped by the Escarpment, especially when combined with lake breeze and/or heat island effects.
- The occurrence of warm stationary anticyclones and accompanying subsidence inversions. These conditions are most common in the autumn and tend to create 'hazy', poor dispersion conditions.

CLIMATOLOGY

Air temperatures in Southern Ontario range from -36°C to 38°C over all seasons. Mean winter and summer temperatures are approximately -7°C to -13°C, 18°C to 21°C, respectively. Frost occurs in Southern Ontario on an average of 38 to 48 percent of the days in a year.

Precipitation amounts are very similar for most months. The Sarnia, London, Kingston, Ottawa, North Bay and two Toronto stations record approximately 78, 91, 87, 88, 96, 76 and 77 cm of precipitation, respectively, throughout the year. The moderating effects of the Great Lakes ensure that almost one-half of the total winter precipitation is in the form of rain. Fog incidents are most frequent in the fall and winter months. Approximately 35 to 63 days in a year can be expected to record a visibility-impairing fog incident in regions of Southern Ontario more than approximately 2 km from the shoreline. Eight to nine hours of sunshine per day can be expected in July, whereas only approximately 2.0 to 2.5 hours per day can be expected in December.

Relatively small climatic variations occur across Southern Ontario. The extreme southwestern region experiences a slightly more moderate climate, with warmer air temperatures, less incidence of frost, and less snowfall than the central and northern regions. The inland and northern sites experience more severe winter conditions. Adequate precipitation frequency and amounts through all seasons ensure the regular washout of pollutants from the atmosphere.

METEOROLOGY

Local surface winds at fourteen stations in Southern Ontario exhibit westerly components over all seasons, although winds from all directions are recorded every season. Maximum surface wind speeds occur during the winter and early spring months, with minimum wind speeds recorded during the summer. The mean annual windspeed for all directions ranges from 3.7 to 5.1 m/s (metres per second). Constant wind conditions generally persist for less than 6 hours indicating that there is no unusual potential for adverse dispersion conditions in Southern Ontario as a consequence of the wind persistence factor. Based on historical atmospheric stability analyses in the study area, neutral stability conditions (i.e. air temperatures are almost uniform vertically) can be expected to occur approximately 32 to 61 percent of the time annually in

Southern Ontario. Unstable conditions (well mixed atmosphere) occur between 15 and 17 percent of the time, while stable conditions (mixing of atmosphere suppressed) occur approximately 23 to 31 percent of the time. Mixing heights (indicating the upper extent of vertical mixing) of approximately 600 m and 1400 m can be expected at mid-day during the winter and summer months, respectively. The annual average wind speed in the mixed layer is approximately 7 m/s. These upper winds are strongest in the spring and fall months due to the passage of frontal cyclones. Winds in the mixed layer are predominantly from the west. The product of the mixing layer wind speed and mixing height is the ventilation coefficient. Ventilation coefficients less than 6000 m^2/s are indicative of poor dispersion conditions at mid-day. This situation occurs 35 to 44 percent of the time in the summer and 60 to 77 percent of the time in the winter in rural inland regions of Southern Ontario. However, the duration of such events is generally less than 6 hours. Atmospheric conditions can be expected to adequately disperse pollutants most of the time in this "central" region as wind conditions are constantly changing. Abatement strategies can be formulated to attempt to accommodate the occurrence of poor dispersion conditions.

CONCLUSIONS AND RECOMMENDATIONS

Relatively small climatic variations occur across Southern Ontario. Similarly, those meteorological parameters which determine the dispersive capacity of the atmosphere do not show significant variations across the study area. Thus, topographical features such as the shoreline of the Great Lakes and St. Lawrence and Ottawa Rivers, the Niagara Escarpment and the effects anticipated from urban centers, become principal factors in determining the potential for poor dispersion conditions to occur on a local scale.

On the basis of the climatological and meteorological considerations of this study, it is concluded that most of Southern Ontario is characterized by atmospheric conditions which would ensure the proper dispersal of emissions from a waste management facility. The areas that are noted below exhibit constraints for dispersal of emmissions:

- any land within approximately 2 km and sometimes up to 30 km of the shoreline of the Great Lakes.
- the region bordered by the Niagara Escarpment and Lake Ontario and Georgian Bay,
- major urban centers and their immediate outlying regions.

Classification of regions of Southern Ontario in terms of the factors which could adversely affect dispersion conditions, is graphically summarized in Figure 8 in the pocket at the back of the report.

The information provided here can be used in conjunction with the results of other background studies in the site selection process. At that time, more site-specific studies of the potential impact of the proposed facility on local air quality should be undertaken. These should include:

- a detailed inventory of all existing sources likely to emit the same pollutants as the waste disposal facility,
- preparation of a projected emission inventory for the proposed facilities based upon data available from the operation of similar waste disposal facilities in other jurisdictions.
- an in-depth review of all existing air quality and meteorological data specific to the proposed area(s),
- establishment of a baseline air quality and meteorological monitoring program to operate for at least one year prior to construction.

1. INTRODUCTION

Assessment of potential environmental impact is an important component of the planning for industrial developments such as the waste management facilities under study by Ontario Waste Management Corporation. Since waste management facilities may involve the handling, treatment and disposal of a wide range of toxic substances, all potential environmental impacts of any proposed facilities must be carefully and thoroughly assessed at an early stage of the development plan.

Both point source and fugitive emissions to the atmosphere can occur at waste management facilities. The environmental impact of such emissions is determined not only by the type and quantity of waste involved, but also by such factors as surrounding land use, topography and meteorological conditions. The objectives of this study were to assemble climatological and meteorological data and to use this information to identify any areas of high air pollution potential which might exist in Southern Ontario. This information can then be used in conjunction with the results of other ongoing studies pertaining to other criteria (waste inventory, transportation, support facilities, land use, soil and hydrogeology, etc.) to select the optimum site, or sites, for the proposed facilities.

A general overview of the climatological and meteorological conditions which prevail in Southern Ontario is presented in this Report. Factors considered are air temperature, frost, precipitation, fog, sunshine hours, surface wind, stabilities, mixing heights, mixing height winds and ventilation coefficients. Quantitative assessment of the potential for poor dispersion of pollutants has been made in terms of the following indices: frequency of stable conditions, surface wind persistence, mixing height and mixing layer wind speeds (the product of which is the ventilation coefficient). These parameters have been considered in the perspective of the dominant features of this region, such as lake breezes, topography, urban heat island and existing air quality trends. A Technical Appendix containing the more detailed figures and tables was prepared and is available under a separate cover.

2. BACKGROUND

2.1 Air Pollution Potential

"Pollution potential" can be defined as a meteorological condition which, given the existence of emissions, would be conducive to the development of poor air quality. The planning of any industrial development should take areas of high pollution potential under special consideration for obvious reasons. In this study, the following parameters have been used as meteorological indices of pollution potential;

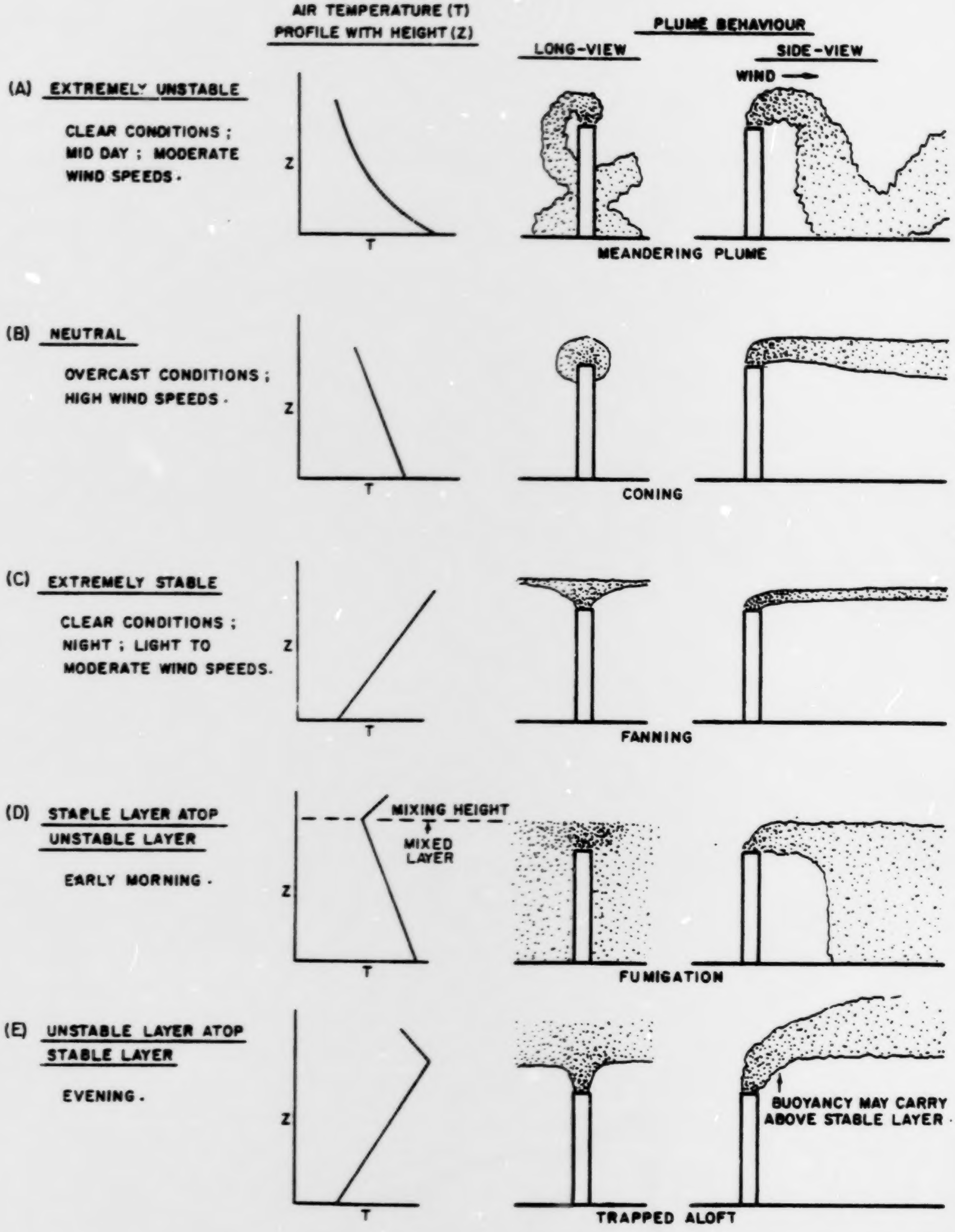
- frequency of stable conditions
- surface wind characteristics, and
- mixing layer wind strengths and mixing layer heights (ventilation coefficient).

Figure 1 illustrates stability class in terms of its effects on a plume. Stable conditions (ground-based temperature inversions) imply that air temperatures increase with height. The slightly cooler air at the surface is more dense than the air above, and is not likely to rise, thus suppressing vertical motion. Pollutants emitted from a stack into this 'environment' will not readily disperse, (see Case C, Figure 1) and will travel as a narrow ribbon until encountering unstable air (and complete mixing as in Case A, Figure 1). Unstable conditions develop when the surface is warmer than the air above. The warmer air is buoyant and will rise, setting up convection and local mixing.

The actual height of the "mixed" layer is a critical parameter. The height is based on the strength of the heating of the surface. For example, on a hot clear summer day, in a rural setting maximum mixing heights can be expected at mid-day, but will gradually decrease until stable conditions (zero mixing height) prevail at night. The minimal pollution situation exists when mixing heights are very high, as this ensures a good dispersal of the pollutants, sufficiently diluting emissions so as to prevent high ground level concentrations. Pollutants released under stable conditions create a more critical situation, as the plume

FIGURE 1

PLUME BEHAVIOUR AS MODIFIED BY STABILITY CLASS


AIR TEMPERATURE (T)
PROFILE WITH HEIGHT (Z)
PLUME BEHAVIOUR
LONG-VIEW
SIDE-VIEW
WIND
(A) EXTREMELY UNSTABLE
CLEAR CONDITIONS ; MID DAY ; MODERATE WIND SPEEDS.
Z
T
MEANDERING PLUME
(B) NEUTRAL
OVERCAST CONDITIONS ; HIGH WIND SPEEDS.
Z
T
CONING
(C) EXTREMELY STABLE
CLEAR CONDITIONS ; NIGHT ; LIGHT TO MODERATE WIND SPEEDS.
Z
T
FANNING
(D) STAPLE LAYER ATOP UNSTABLE LAYER
EARLY MORNING.
MIXING HEIGHT
MIXED LAYER
Z
T
FUMIGATION
(E) UNSTABLE LAYER ATOP STABLE LAYER
EVENING.
Z
T
BUOYANCY MAY CARRY ABOVE STABLE LAYER.
TRAPPED ALOFT

will travel without dispersing until intersecting a mixed atmosphere, where the pollutants will immediately be brought to ground level (fumigation), resulting in a very high ground level concentration at that point. Fumigation conditions occur frequently in the early morning hours as illustrated in Case D, Figure 1. As well, this situation occurs often near large bodies of water. Heating of the land surface (in the summer) or an open water surface (in the winter) will create unstable, well mixed atmospheric conditions above the surface. Close proximity to another surface experiencing stable conditions (water in summer; land in winter) will set up a circulation which can cause fumigation situations to occur. Urban centres are well known to act as heat islands during the night, often creating a local circulation cell with the stable rural air surrounding them.

Mixing layer winds are important in that they affect the dispersal of pollutants and will eventually determine the downwind receptor. Strong winds will not allow the plume to spread extensively in the horizontal and vertical directions, whereas light winds will allow dispersion in all direction as a function of atmospheric stability.

2.2 Lake Breeze Effects

Local wind regimes induced by a lake or shoreline, in the absence of general regional winds, may have a major influence on air pollution dispersion. Pressure differences due to differential heating of air and differences in surface roughness are the driving force behind lake and land breeze circulations (Hewson and Olsson, 1967). Stable marine air is advected inland in the daytime, and will result in a lowering of mixing heights in the near shore areas, and the formation of an internal boundary layer, (stable air atop a surface-based unstable layer). Plumes from relatively high coastal stacks will travel inland with little dispersion in the stable flow until they intersect the internal boundary layer several kilometres inland where the underlying convective turbulence rapidly mixes the pollutants to ground level, in potentially high concentrations (Portelli, 1981). The actual circulation cell may reach more than 30 km inland (Hewson and Olsson, 1967). This circulation reverses directions at night (offshore flow at surface level because the land is cooler than the body of water), and pollutants which appear to be travelling out over the water surface will rise and be returned aloft toward the shore because of the closed-cell nature of the sea breeze phenomenon (Frisken, 1973). In the past, shoreline environments have been chosen for industrial development and population centers, and numerous examples now exist in which lake breeze effects are a major factor resulting in high pollutant levels in urban and industrialized areas. The complexity of dispersion patterns near a shoreline make the siting of a facility which emits any type of pollutant within 30 kilometres of the shore unattractive because of these complex dispersion patterns. This 30 km band should be avoided especially in urban areas unless other factors strongly favour siting within it (Hewson and Olsson, 1967).

2.3 Urban Heat Island

The climatic elements in the urban environment are significantly different from rural climatic elements. A city will characteristically experience warmer air temperatures, lower humidity, higher dust loadings, less ultraviolet radiation, cloudier skies, lower wind speeds, and more precipitation than the adjacent countryside (Hare and Thomas, 1974). Urban climates are formed as a result of the cumulative effects of the following factors:

1. The city is built of different materials than those of rural areas. The concrete, bricks, and tarmac have a higher heat capacity than the soils of rural areas, thus storing large amounts of heat in the day, and releasing it at night.
2. Energy is artificially released into the atmosphere. Huge quantities of waste heat are dispersed into the urban air from industrial activities, space heating and transportation.
3. Pollutants emitted into the urban atmosphere change the energy/radiation balance. For example, CO_2 emissions

will absorb solar radiation which has been reflected from the Earth as well as outgoing longwave radiation, and re-emit it as incoming longwave radiation (toward the surface), increasing air temperatures (i.e., the "greenhouse effect").

4. A city differs in roughness and geometry from the rural landscape and interacts with winds in a different way.

Section 2.4 explains topographic effects in more detail, but channelling effects such as are relevant for river valleys are evidenced on a smaller but more complex scale within street "canyons". Due to the many obstacles encountered by the winds, wind speeds recorded within a city are generally lower, but highly variable, when compared to rural winds.

Summer and early autumn urban heat islands can experience nocturnal temperature excesses of 6°C or more than the surrounding rural area. Clear winter nights may experience strong heat islands to a slightly lesser degree, due to the decreased amount of solar radiation input.

Under strong wind conditions (neutral stability), natural ventilation will disperse pollutants downwind of the source region. However, under light wind conditions urban air-sheds develop their own "mixing depths" due to the urban heat island effect, which effectively traps the polluted atmosphere. In the early evening, when the city is generally experiencing neutral or unstable conditions, cooler stable air is advected over the city from the rural countryside (where radiation inversions are already forming). Until the city surfaces are cool enough to allow the formation of stable conditions, any existing or emitted pollutants will be trapped within a limited mixing zone by the stable air above. Nocturnal mixing heights may be of the magnitude of 200 m, which is quite low in comparison to "typical" day-time mixing heights, annually, of 1000 m in Southern Ontario.

2.4 Topography

Topography is an important factor in determining local variations in the climate and meteorology of Southern Ontario. Southern Ontario is almost an island, bounded by the Great Lakes on the south, west and northwest, and by the St. Lawrence and Ottawa Rivers to the east. The Niagara Escarpment skirts the western shores of Lake Ontario, extending inland north to Georgian Bay. The Onondaga Escarpment is situated near the northeast shores of Lake Erie, but is not as prominent as the Niagara Escarpment. Figure 2 illustrates the location of the escarpment, as well as the generalized regions of Southern Ontario. The topography ranges from elevations of 180 m near the shorelines of Lake Erie and Lake Huron to a maximum of 500 m inland.

The Niagara Escarpment is the main topographical feature of Southern Ontario. This landform tends to trap incoming cold stable air from Lake Ontario during spring and summer when thermal contrasts between land and lake are greatest, creating a stagnant inversion situation along the coast from Hamilton to Niagara-on-the-Lake. The St. Lawrence and Ottawa River basins are subject to valley circulations, especially in regions where the valleys are long and sloping. Cold, stable air may be trapped in the basin, especially during the spring, summer and winter (when the river freezes) due to the air/water temperature difference. Under these conditions, pollutants released in the valley then accumulate to high concentrations. In such river valleys, the cold air will tend to flow towards lower parts of the valley, with diurnal wind patterns only serving to recycle emissions. Pollutants move down the valley at night only to return in the daytime when the wind shifts.

2.5 Recent Air Quality Trends

Trends in air pollution levels in Southern Ontario can be assessed in terms of ambient levels (from both man-made and natural sources) and in terms of the primary emission of pollutants into the

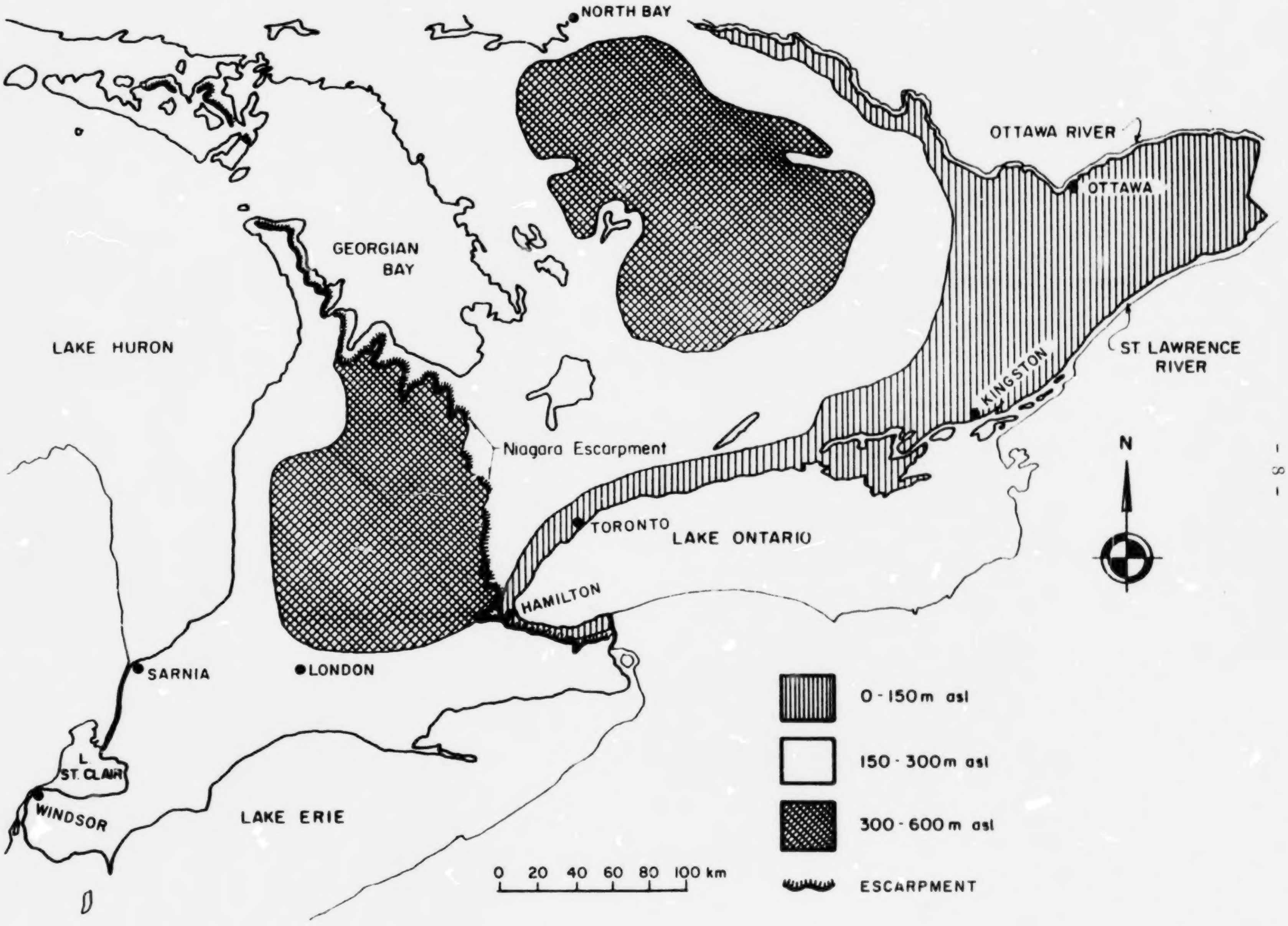

NORTH BAY
OTTAWA RIVER
OTTAWA
GEORGIAN BAY
LAKE HURON
KINGSTON
ST LAWRENCE RIVER
Niagara Escarpment
N
TORONTO
LAKE ONTARIO
HAMILTON
SARNIA
LONDON
L. ST. CLAIR
WINDSOR
LAKE ERIE
0 20 40 60 80 100 km
0 - 150m asl
150 - 300m asl
300 - 600m asl
ESCARPMENT

FIGURE 2 GENERALIZED TOPOGRAPHIC REGIONS OF SOUTHERN ONTARIO

atmosphere. Ambient levels of total suspended particulates (TSP) can be used as a general indicator of the prevailing air quality within a local airshed. Anthropogenic contributions to TSP levels, for example, include smoke from combustion, dust from construction, mining, metal smelting and processing, grinding processes and transportation. Natural sources, such as volcanoes, forest fires and wind blown soil, and the long-range transport of particulate matter are also significant contributors to ambient levels of TSP. Daily levels can be influenced by meteorological factors such as precipitation and mean wind speed and can create fluctuations, from year to year, in the number of daily TSP values exceeding the criterion (Heidorn, 1981).

TSP levels in Ontario from 1971 to 1980 have decreased slightly with time, from average annual values (for the entire monitoring network) of 95 $\mu g/m^3$ in 1971 to 63 $\mu g/m^3$ in 1980 (Table 1). In 1971 only 11% of the 54 stations operating met the annual criterion, whereas 48% of the 133 stations met this criterion in 1980. The 24-hour criteria, in Ontario, was met only 4% of the time in 1971 (88 stations), with exceedences decreasing generally to 1980, when 30% of the 184 stations operating met the 24-hour criterion. Table 1 presents these 24-hour and annual trends for the years 1971 to 1980 inclusive.

A general assessment of the extent to which specific local airsheds in Southern Ontario are currently being utilized is suggested for future studies to give an indication of those areas in which ambient criteria are most likely to be exceeded. Natural and anthropogenic emission inventories for a number of pollutants are available and also should be consulted.

TABLE 1

Total Suspended Particulate Matter Trends In The Last Decade

Year	Annual No. of Stations	Annual Network Average ($\mu g/m^3$)	Annual % Meeting Criterion*	24-Hour No. of Stations	24-Hour % Meeting Criterion**	24-Hour Total Exceedences of Criterion
1971	54	95	11	88	4	1,350
1972	71	96	16	105	13	1,559
1973	69	90	17	109	8	1,848
1974	96	76	28	129	14	2,590
1975	99	65	41	143	15	1,845
1976	109	64	47	142	13	2,177
1977	115	61	57	146	17	1,592
1978	121	59	57	155	16	1,821
1979	129	65	44	159	15	2,138
1980	133	63	48	184	30	1,830

* Annual criterion 60 $\mu g/m^3$

** 24-hour criterion 120 $\mu g/m^3$

3. CLIMATCLOGY

The climate of Southern Ontario is governed by continental Arctic (winter), maritime Arctic and maritime Polar (summer), and modified maritime tropical (autumn) air masses. Since Southern Ontario lies in the normal track of migrating high and low pressure centers at all times of the year, great variation in the day-to-day weather may be expected around the seasonal mean. Thus, while the climate is predominantly a seasonal one, Southern Ontario often experiences short periods of unseasonal weather which seldom last longer than three to seven days (Munn et al., 1963).

The data presented in this section provide an overview of general climatic conditions prevailing in Southern Ontario. The variables considered directly or indirectly affect the mechanisms involved in the atmospheric pathways of pollutants and, therefore, are important parameters whereby the relative potential for adverse environmental impact at alternate sites can be assessed. Furthermore, subsequent evaluations of specific proposed sites, such as disperion and deposition modelling of the potential impact of emissions on the local environment, will require these data as input.

Point source emissions behave differently under different ambient air temperature conditions. Precipitation statistics will aid in predicting deposition patterns of pollutants. Solar radiation characteristics are an important factor in determining prevailing stability conditions. This information on existing climatological conditions may also prove to be a useful tool in plant design and operation studies. Air temperatures (means and extremes), frost frequencies, precipitation, fog, and sunshine hours are presented and discussed for the Toronto, London, Sarnia, Kingston, Ottawa and North Bay areas.

3.1 Air Temperature

Geographical air temperature variations are commonly encountered throughout Southern Ontario. Factors such as latitude, and the moderation offered by the proximity of a site to a large body of water are important. Urban/rural temperature differences can be expected, as outlined in Section 2.3. In most cases, however, there is only one local monitoring station, generally located outside of the urban area at the airport.

Mean annual and monthly daily temperature ranges, and temperature extremes for Toronto, London, Sarnia, Kingston, Ottawa and North Bay are available from historical climatological records (Appendix 1). Air temperatures in Southern Ontario can be expected to range seasonally from -36°C to 38°C, with generally similar trends emerging at all sites. Probable average daily temperatures for January are close to -7°C near the lakes and in the southern inland regions, decreasing to -11°C and -13°C at Ottawa and North Bay, respectively. July average temperatures are near 21°C at all stations with the exception of North Bay, where the average is 18°C. Annual average daily temperatures in the Southern Ontario region are approximately 7°C in southern coastal and inland sites, 6°C in Ottawa, and 4°C in North Bay (Environment Canada, 1982). North Bay experiences a slightly cooler climate due to its comparatively northern latitude, and to the absence of moderating water bodies.

3.2 Frost

Local minimum temperatures are highly sensitive to topography, soil type and soil conditions. Late spring and early fall frosts may result when either of two types of weather conditions prevail; nights with cold northerly winds which produce a general freeze; or, calm, clear nights with heat lost as outgoing longwave radiation, enabling cold air to drain off the slopes and into the depressions. Areas on the lee side of the lakes, however, sometimes escape these late spring and early fall frosts due to the moderating effects of sizeable bodies of water. Cooling is greatest over peat soils. More rapid cooling is found over sands than over loams and clays. Soils in Southern Ontario tend to vary locally, with clay and sandy soil predominating among occasional glacial till deposits. The landscape is gently rolling, with the exception of the Escarpment, (rising to elevations of over 300 m above sea level) and the St. Lawrence and Ottawa River valleys.

Data for the mean annual and monthly days with frost are available for the Toronto (2 sites), London, Sarnia, Kingston, Ottawa and North Bay climate stations from historical records (Appendix 2). The months of June, July and August, only, are frost-free across the region of Southern Ontario. Sarnia appears to experience the least number of days with frost (137 days per annum, on average). This station is situated approximately 2 km from Lake Huron, and can be expected to experience a slight moderating effect from the lake. The North Bay site shows the most frequent occurrence of frost (174 days per annum, on average) due to its relatively northern, inland location. Average annual data from the stations indicate that frost occurs on an average of 47 percent of the days in a year in Ottawa and North Bay, and 40 percent of the days in a year at more southerly stations (Environment Canada, 1982).

3.3 Precipitation and Fog

Mean monthly historical climatological records of rain, snow and total precipitation are available for the Toronto, London, Sarnia, Kingston, Ottawa and North Bay stations (Appendix 3). Average annual total precipitation for the major monitoring stations in Southern Ontario ranges from 76 cm (Toronto) to 96 cm (North Bay). North Bay and London both receive more than 90 cm of total annual precipitation because they are situated in inland "precipitation belts". Toronto and Sarnia both record lesser amounts of precipitation (approximately 77 cm of precipitation), attributable to their proximity to Lake Ontario and Lake Huron. The effect of cold stable air over the lake in the spring, summer and fall can suppress the local formation and infringement of convective clouds. Kingston and Ottawa receive approximately 87 cm of precipitation annually. Kingston is situated to the lee of Lake Ontario. Air masses travelling from the west bringing precipitation will increase their moisture content after travelling over the lake, especially in the fall and early winter, ensuring increased rainfall amounts. Ottawa is situated in a mild precipitation "belt", especially during winter months. On average, Southern Ontario can expect between 77 and 96 cm of precipitation in a year.

Snowfall amounts are recorded as water equivalents to enable direct comparison with rain events. The 1:10 ratio which is used to convert the snow assumes that, when the snow is melted, its density is increased tenfold. This ratio is applicable at all times except during snowmelt season, when the ratio decreases with time until it approaches 1:1 in the spring. Snowfall constitutes between 16 and 26 percent of the total precipitation in the region, as measured at the seven stations (Toronto Airport 16%; Toronto Downsview 18%: London 20%; Sarnia 16%; Kingston 20%; Ottawa 25%; North Bay 26%). Measureable snowfalls occur between the months of October and April. Winter rainfall is appreciable as well, accounting for approximately one-third at North Bay and Ottawa, and one-half of the total precipitation at other stations. The heaviest snowfalls recorded in 24 hours for the seven sites were: 40 cm - Toronto Airport (4.0 cm water equivalent); 35 cm - Toronto Downsview (3.5 cm water equivalent); 57 cm - London (5.7 cm water equivalent); 48 cm - Sarnia (4.8 cm water equivalent); 46 cm - Kingston (4.6 cm water equivalent); 41 cm - Ottawa (4.1 cm water equivalent); 48 cm - North Bay (4.8 cm water equivalent). Southern Ontario can expect an average of about 42 to 85 days each year of measureable snow, with the maximum expected in the "snow-belts" and at the more northern stations.

Rainfall in Southern Ontario occurs during most months with a summer maximum at all stations. The heaviest rainfalls recorded in 24 hours were: 12.1 cm Toronto Airport; 6.6 cm Toronto Downsview; 8.3 cm London; 9.8 cm Sarnia; 12.9 cm Kingston; 8.0 cm Ottawa; 9.6 cm North Bay. On average, Southern Ontario can expect between 99 and 111 days each year with measurable rainfall (Environment Canada, 1982).

The presence of condensed moisture in the air, particularly in the form of fog, increases the possibility of encountering an air pollution event as the prevailing conditions conducive to the formation of both situations are often very similar. Radiation fog occurs generally at night, when highly humid air experiences a rapid temperature drop (generally on a clear night). Advection fog is experienced during the winter or cold months when a relatively warm humid air mass moves into a region. Generally this situation occurs under overcast skies. Steam fog occurs only in close proximity to water bodies, when the temperature difference between the land and water is greater than 10°C. Fog formation in all situations is enhanced when light winds, stable atmospheric conditions and high levels of humidity prevail.

Based on available historical records from stations in Southern Ontario (Appendix 4), the highest frequency of fog occurrence, at Toronto, London and Ottawa, is during the fall and winter months, whereas, the lowest incidence of fog is during the midsummer period. North Bay, however, records at least 2 or 3 more days of fog every month than these other stations. The cooler air temperatures encountered here during all seasons most likely increase the incidents of radiation fog. Annually, an average of approximately 35 to 63 days in a year can be expected to record a visibility-impairing fog incident in the 'inland' portions of Southern Ontario (more than about 2 km away from the shorelines) (Environment Canada, 1971). The atmospheric conditions conducive to fog formation are also conducive to poor air quality. However, the southern portion of Southern Ontario does not experience frequent fogging incidents 'inland'. The more frequent incidents recorded at North Bay are not of a large enough magnitude to indicate increased air pollution potentials.

3.4 Sunshine Hours

Southern Ontario routinely experiences local daily differences in hours of sunshine due to variable cloud cover. In general, however, there is a minimum of bright sunshine in December and a maximum in July.

The sun is highest in June, but the greater cloud cover during this month reduces the number of hours of sun. In December, the total sunshine in Southern Ontario is approximately 2.0 to 2.5 hours per day, while in July it is 8 to 9 hours per day (Hare and Thomas, 1974). The region around the shores of Lake Ontario experiences slightly more sunshine, annually and seasonally, than does the rest of Southern Ontario, especially the more northern sections. This is as a result of slightly greater amounts of cloud cover and precipitation in these regions.

4. METEOROLOGY

The meteorological conditions in the lower regions of the atmosphere are especially important in determining the dispersive capacity of the atmosphere on local and regional scales. Wind speed, wind direction and temperature stratification (temperature variation with height) are the most important variables. In addition, several specific features, or phenomena, of Southern Ontario also must be noted in considering the potential for air pollution episodes to occur in this area:

1. lake breeze effects (Section 2.2), resulting from the spring and summer stable conditions over the lake, which when advected onto the shore, create locally poor vertical diffusion within approximately 2 km of the Great Lakes shorelines.
2. warm stationary anticyclone and accompanying subsidence inversions, which occasionally shroud the region in haze, particularly in autumn.
3. urban heat island effects (Section 2.3), especially in major urban developments along the Great Lakes shorelines.
4. topographical features such as the Niagara Escarpment which may serve to trap pollutants, especially when combined with the lake breeze effects from the Great Lakes (Section 2.4).
5. frontal inversions over the St. Lawrence and Ottawa River Valleys, mainly in autumn and winter. Cold air is occasionally trapped in these valleys, producing a high pollution potential sometimes after only a few hours.

In the following sections the available data and information for the Southern Ontario areas of interest are discussed and used to define the atmospheric dispersion conditions which can be expected to occur. These results are then used to assess the relative potential for adverse environmental effects to occur in these areas as a result of the poor dispersion of point source emissions.

4.1 Surface Winds

Wind frequency distributions, classified according to wind direction origin for Toronto, London, Sarnia, Mount Forest, Centralia, Simcoe, Windsor, Trenton, Kingston, Wiarton, Muskoka, Ottawa and North Bay, are plotted on a map of SouthernOntario in Figure 3 (Annual), Figure 4 (summer; months of April, May, June, July, August and September averaged) and Figure 5 (winter; months of October, November, December, January, February and March averaged). The summer and winter distinction was made based on similarities in wind directions exhibited during each six month period. Generally, winds from all directions are experienced in Southern Ontario and frequent changes in wind speed and direction may be experienced as migrating low and high pressure systems move through an area. However, all of the annual wind frequency distributions indicate that winds are generally out of the west, combined with local influences. For example, the prevailing winds experienced in the regions immediately adjacent to the Great Lakes, the St. Lawrence River and the Ottawa River interact with the lake breeze effects. During the summer, much of Southern Ontario experiences predominantly southwesterly or northwesterly wind components. Local factors often influence wind directions. For example, the Sarnia area receives north winds frequently in the summer, which can be attributed to the influence of Lake Huron. During the winter months, the westerly component is strongest in Southern Ontario.

Historical mean wind speed data are available for the Toronto, London, Sarnia, Simcoe, Mount Forest, Centralia, Windsor, Trenton, Kingston, Wiarton, Muskoka, Ottawa and North Bay stations (Appendix 5). Maximum average wind speeds occur during the winter and early spring months at all the Southern Ontario stations recording wind speed. Lightest winds are recorded during the summer months. The annual average windspeed in

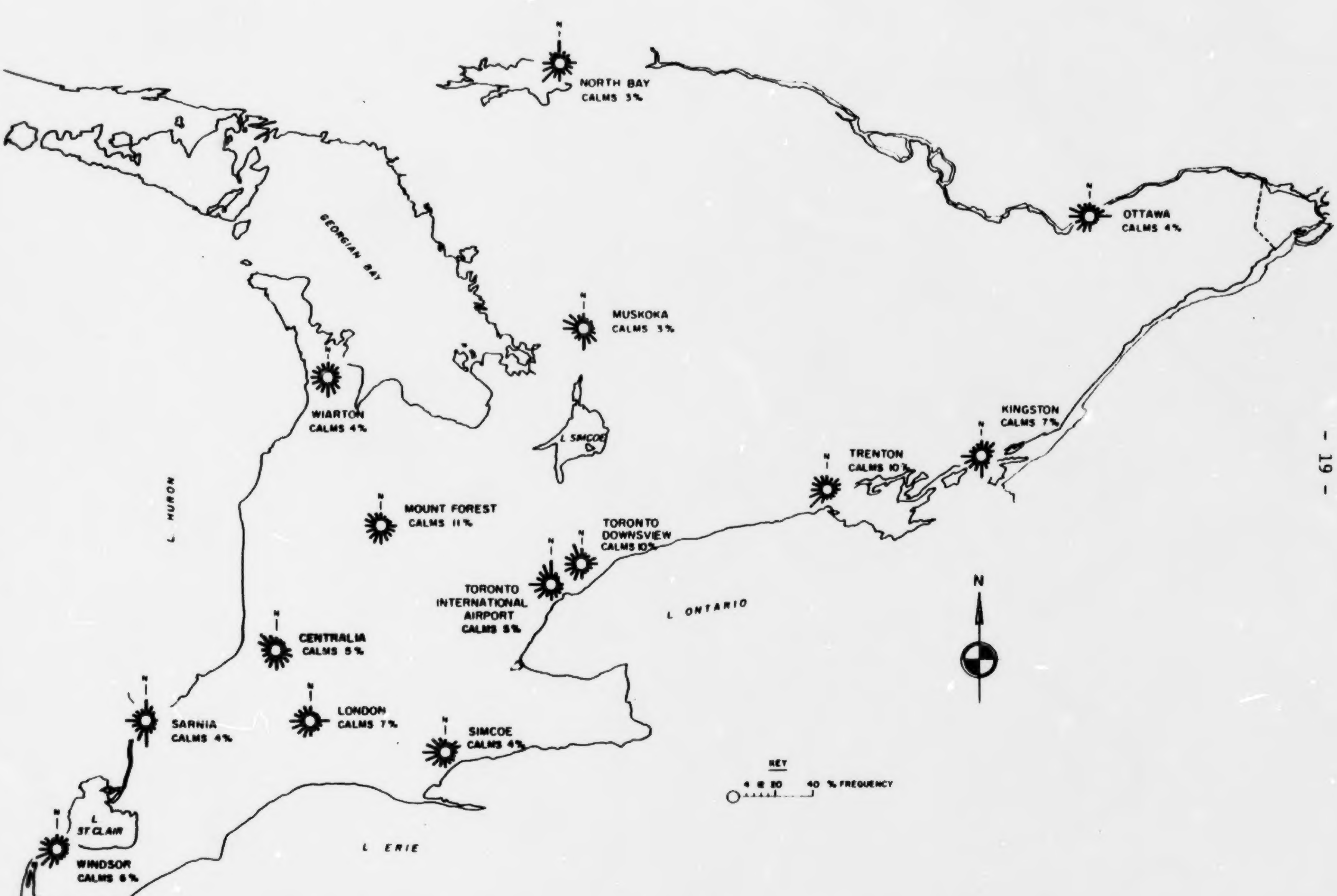

N
NORTH BAY
CALMS 3%
N
OTTAWA
CALMS 4%
GEORGIAN BAY
N
MUSKOKA
CALMS 3%
N
WIARTON
CALMS 4%
L SIMCOE
N
KINGSTON
CALMS 7%
N
TRENTON
CALMS 10%
L HURON
N
MOUNT FOREST
CALMS 11%
N
TORONTO
DOWNSVIEW
CALMS 10%
N
TORONTO
INTERNATIONAL
AIRPORT
CALMS 5%
N
L ONTARIO
N
CENTRALIA
CALMS 5%
N
SARNIA
CALMS 4%
N
LONDON
CALMS 7%
N
SIMCOE
CALMS 4%
KEY
4 12 20 40 % FREQUENCY
N
L
ST CLAIR
WINDSOR
CALMS 6%
L ERIE

FIGURE 3 ANNUAL WIND DIRECTION FREQUENCIES FOR SOUTHERN ONTARIO STATIONS

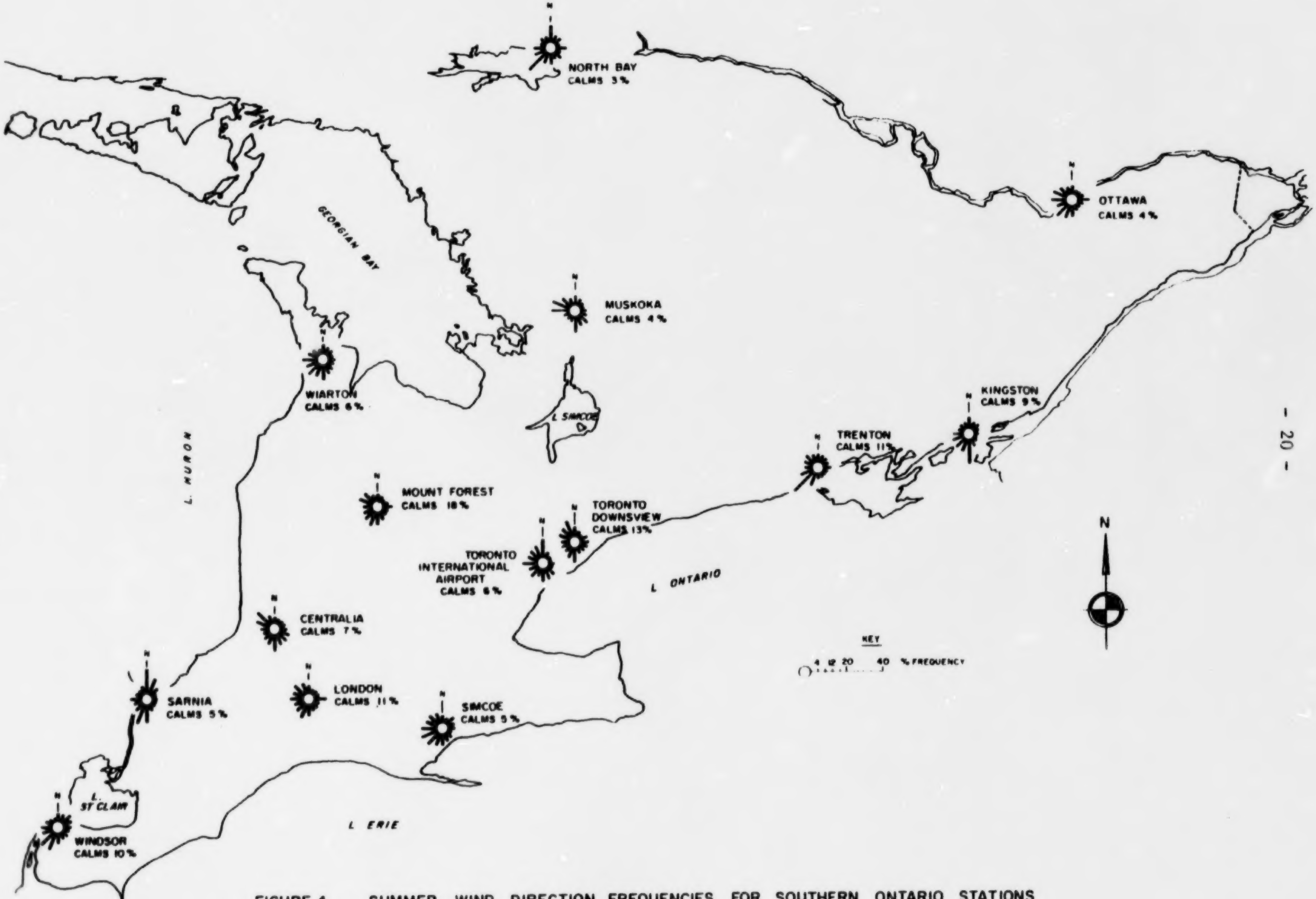

N
NORTH BAY
CALMS 3%
GEORGIAN BAY
N
MUSKOKA
CALMS 4%
N
OTTAWA
CALMS 4%
N
WIARTON
CALMS 6%
L SIMCOE
L HURON
N
KINGSTON
CALMS 9%
N
TRENTON
CALMS 11%
N
MOUNT FOREST
CALMS 18%
N
TORONTO
DOWNSVIEW
CALMS 13%
N
TORONTO
INTERNATIONAL
AIRPORT
CALMS 6%
L ONTARIO
N
N
CENTRALIA
CALMS 7%
KEY
4 12 20 40 % FREQUENCY
N
SARNIA
CALMS 5%
N
LONDON
CALMS 11%
N
SIMCOE
CALMS 5%
L
ST CLAIR
N
WINDSOR
CALMS 10%
L ERIE

FIGURE 4 SUMMER WIND DIRECTION FREQUENCIES FOR SOUTHERN ONTARIO STATIONS

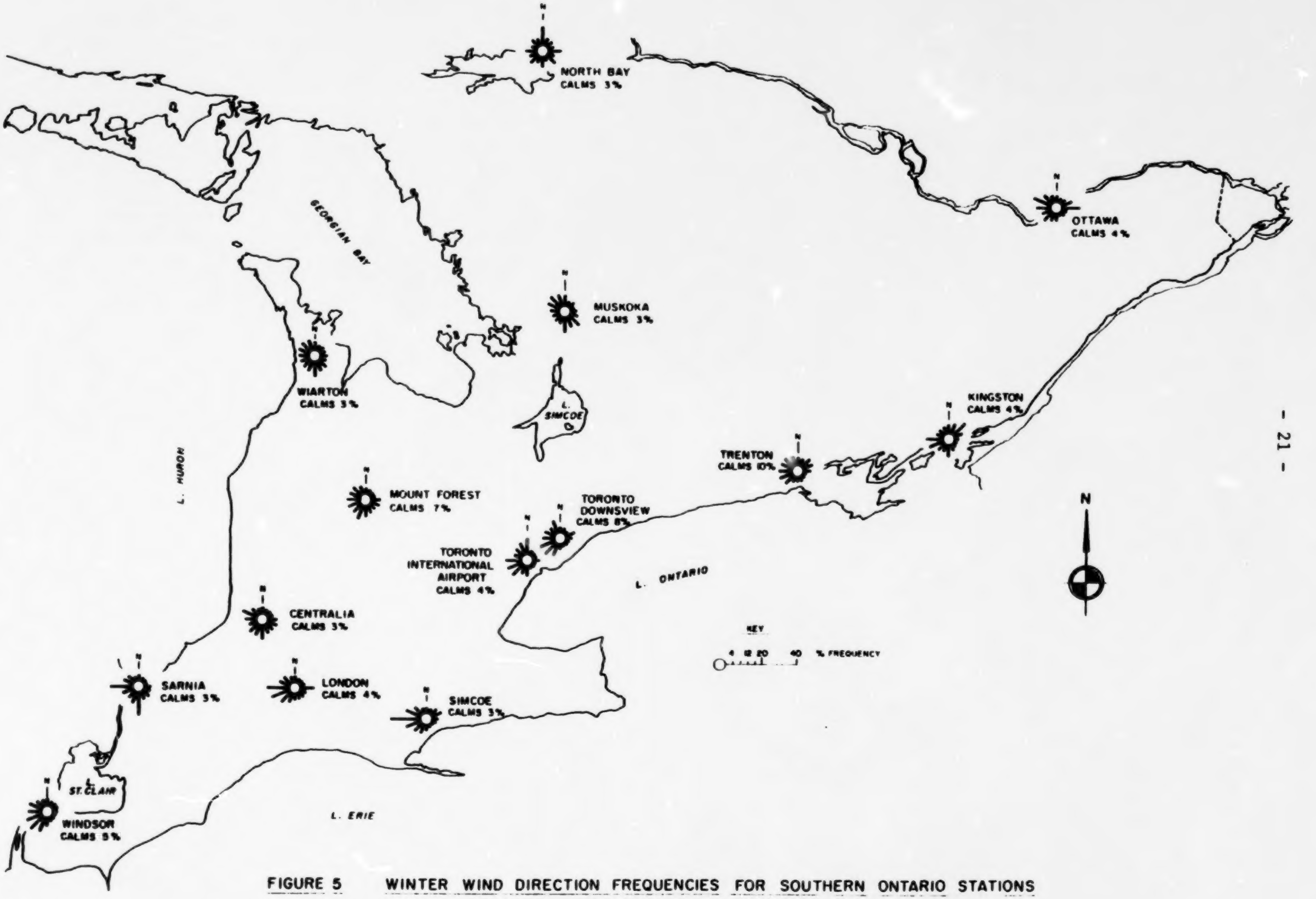

N
NORTH BAY
CALMS 3%
GEORGIAN BAY
N
OTTAWA
CALMS 4%
N
MUSKOKA
CALMS 3%
N
WIARTON
CALMS 3%
L. SIMCOE
N
KINGSTON
CALMS 4%
N
TRENTON
CALMS 10%
L. HURON
N
MOUNT FOREST
CALMS 7%
N
TORONTO
DOWNSVIEW
CALMS 8%
N
TORONTO
INTERNATIONAL
AIRPORT
CALMS 4%
L. ONTARIO
N
N
CENTRALIA
CALMS 3%
KEY
4 12 20 40 % FREQUENCY
N
SARNIA
CALMS 3%
N
LONDON
CALMS 4%
N
SIMCOE
CALMS 3%
L. ST. CLAIR
N
WINDSOR
CALMS 5%
L. ERIE

FIGURE 5 WINTER WIND DIRECTION FREQUENCIES FOR SOUTHERN ONTARIO STATIONS

Southern Ontario for all directions ranges from 3.7 to 5.1 metres per second (m/s). With the exception of slightly lower wind speeds recorded at the Muskoka station, and slightly higher wind speeds recorded at the Wiarton and Centralia stations, there is little variation from the average wind speed conditions among the other stations throughout the remainder of the study area.

The average wind speed and direction conditions discussed above are useful in defining relatively long-term average dispersion conditions which can be anticipated in the study area, but do not provide any insight as to the duration or persistence of any specific set of conditions (bad or otherwise) which might be experienced. The persistence of poor dispersion conditions is a particularly important parameter because of the resulting potential for the accumulation of emissions, resulting in ground level concentrations well beyond those that can arise from direct impingement (see Section 2.1). Such information is available in the form of 'hourly duration analyses' in which the persistence of winds by wind speed class and direction are given.

A summary of the persistence of winds in Southern Ontario has been prepared in terms of data for Toronto (1971-1980), London (1971-1980), Sarnia (1973-1980), Kingston (1971-1980), Ottawa (1971-1980) and North Bay (1971-1980) (Appendix 6). These six stations provide representative estimates for Southern Ontario. The wind classes were defined as ranges of wind speed on the "Beaufort" scale of winds. These are as follows:

0 - calm
0.5 to 2.9 m/s - representing light winds
3.0 to 6.9 m/s - representing light to moderate winds
≥ 7.0 m/s - representing moderate to strong winds.

Eight direction classes were provided by combining adjacent compass points (N+NNE, NE+ENE, E+ESE, SE+SSE, S+SSW, SW+WSW, W+WNW, NW+NNW).

The greatest wind persistence frequency is six hours or less at all six sites. On a local scale, wind conditions representing the most severe pollution potential are the calms and light winds. Persistent calms and/or light winds lasting from 25 to 48 hours and longer are of greatest significance to poor air quality (Shaw et al., 1972). It is apparent that the frequency of occurrence of calms/light winds lasting for more than a day (i.e., more than 24 hours) is zero at all six sites. Furthermore, the frequency of occurrence of calm or light wind conditions persisting for 13 to 24 hours is less than one percent.

On a comparative basis, there is some apparent difference in the persistence of wind conditions at the six monitoring sites. Kingston, Ottawa and North Bay could be said to show a slightly greater tendency for persistent wind conditions, as indicated by the figures for total persistence percent:

	Time Interval (hrs)		
	1-6	7-12	13-24
Toronto	97.5	2.2	0.3
London	95.8	3.8	0.4
Sarnia	93.2	5.9	0.9
Kingston	90.2	8.0	1.8
Ottawa	90.6	7.7	1.7
North Bay	90.1	7.9	2.0

This increased persistence is associated with all wind classes, but can be attributed specifically to a higher than average persistance of west quadrant winds in the three areas.

4.2 Atmospheric Stability

Stability is an extremely important factor in determining the dispersive capacity of the lower atmosphere where airborne pollutants are usually confined. Stability is strongly dependent on temperature stratification (from surface to 10 km height), wind conditions and topography. Categories of atmospheric stability are defined as follows:

Unstable - Unstable conditions occur when there is a marked decrease in ambient air temperature with height (essentially cold air on top of warm air). As solar radiation heats the ground, turbulence is caused by heat fluxes generated from the surface (thermal turbulence), as the warm air below attempts to rise. However, contributions to the turbulent field also may come from the variations of the wind field with height and its interaction with roughness elements on the surface (mechanical turbulence).

Neutral - Neutral conditions occur when there is a 1°C decrease or more with every 100 m increase in height. The tendency is for temperature to become uniform throughout the mixed layer (the vertical "layer" through which dispersion takes place). Neutral mixed layers are really the final state of initially unstable layers. Neutral conditions exist for overcast situations during night or day.

Stable - Stable conditions occur when there is an increase in ambient temperature with height (i.e., warm air on top of cold air). The cold air nearest the surface is more dense, and will tend to suppress vertical atmospheric motions and thus the dispersive capacity of the atmosphere. This situation will trap pollutants in the vicinity of the emission source if winds are light, establishing a high pollution potential. Inversions tend to be representative of strongly stable conditions, with temperature increases greater than a few degrees Celsius for every hundred metres of height. Inversions are common near the ground at night over rural terrain.

Stabilities are classified according to net radiation and surface wind speed into Pasquill's Stability Categories using the STAR programme (originating from the National Climatic Centre of the National Oceanic and Atmospheric Administration). The six stability categories are described in Table 2. For the STAR Day/Night version, the D category is separated into two classes; D-Day and D-Night representing day-time and night-time neutral conditions, respectively; the E and F categories are combined into one stable classification.

TABLE 2

Meteorological Stability Categories (after Turner 1970)

	Daytime Insolation			Night-time Conditions	
Surface Wind Speed (ms^{-1})	Strong	Moderate	Slight	> 4/8 cloudiness	≤ 3/8 cloudiness
2	A	A–B	B		
2 - 3	A–B	B	C	E	F
3 - 5	B	B–C	D	D	E
5 - 6	C	C–D	D	D	D
6	C	D	D	D	D

A. Extremely unstable conditions.
B. Moderately unstable conditions.
C. Slightly unstable conditions.
D. Neutral conditions*.
E. Slightly stable conditions.
F. Moderately stable conditions.

---

* The neutral condition D, should be assumed for overcast conditions during day or night.

Table 3 presents the results of STAR analyses for Toronto, London, Sarnia, Kingston, Ottawa and North Bay. These six stations recorded very similar stability patterns in general, when averaged over a ten year period. The predominant class is D (neutral). From the analysis, neutral (D) conditions can be expected to occur about 52 to 61 percent of the time annually in Southern Ontario, with D-Day and D-Night conditions occurring with approximately equal frequency. Stable conditions develop approximately 23 to 31 percent of the time in Southern Ontario. Unstable conditions occur 15 to 17 percent of the time; 9 to 11 percent for slightly unstable conditions and 4 to 7 percent for moderate and strong instabilities.

From a local pollution standpoint, stable conditions (which, in rural setting, generally occur nocturnally under light-calm surface winds), represent a high pollution potential. Seasonally, the summer and fall months experience stable conditions most frequently on average, 26 to 36 percent of the time in the summer (winds are lightest in the summer), and 23 to 33 percent of the time in the fall. The winter months record the least number of stable conditions (winds are strongest in the winter); 17 to 28 percent, with spring months recording 22 to 27 percent occurrence. The slight variability among the six stations can be attributed to local factors, such as the exposure of the monitoring site (an exposed site will record higher wind speeds than a slightly sheltered site), proximity to local influences, i.e. lakes and rivers and their wind pattern effects, and latitude (i.e. Ottawa and North Bay may record a higher incidence of winter stable conditions as a result of experiencing slightly longer winter nights than the Great Lakes stations.

During the autumn months, the presence of a warm stationary anti-cyclone will subject the entire Southern Ontario region to the accompanying subsidence inversion. Such large scale synoptic weather features often result in very similar ground level stabilities existing at several monitoring stations in the area at one time. Frontal inversions over the Ottawa and St. Lawrence river valleys for example, could be extended for long periods due to trapping in these valleys.

TABLE 3

Seasonal and Annual STAR Analyses (1971-1980) % of Occurrence

Toronto

			Stability Class			
Season	A	B	C	D-Day	D-Night	E&F
Winter (D,J,F)	0	1	4	27	47	21
Spring (M,A,M)	1	5	10	31	27	26
Summer (J,J,A)	0	10	18	24	13	35
Autumn (S,O,N)	2	3	8	27	30	30
Annual	1	5	10	27	29	28

London

			Stability Class			
Season	A	B	C	D-Day	D-Night	E&F
Winter (D,J,F)	0	1	4	27	50	18
Spring (M,A,M)	1	5	9	32	27	26
Summer (J,J,A)	2	10	17	25	12	34
Autumn (S,O,N)	0	3	7	28	32	30
Annual	1	5	9	28	30	27

Sarnia

			Stability Class			
Season	A	B	C	D-Day	D-Night	E&F
Winter (D,J,F)	0	1	4	29	50	17
Spring (M,A,M)	1	5	9	32	29	24
Summer (J,J,A)	2	12	15	24	15	32
Autumn (S,O,N)	0	3	8	30	31	28
Annual	1	5	9	29	31	25

TABLE 3 (Cont'd)

Seasonal and Annual STAR Analyses (1971-1980)
% of Occurrence

Kingston

Season	Stability Class A	B	C	D-Day	D-Night	E&F
Winter (D,J,F)	0	1	5	28	46	20
Spring (M,A,M)	0	5	11	35	26	23
Summer (J,J,A)	1	8	20	30	15	26
Fall (S,O,N)	0	2	7	33	35	23
Annual	0	4	11	32	30	23

Ottawa

Season	Stability Class A	B	C	D-Day	D-Night	E&F
Winter (D,J,F)	0	2	6	23	41	28
Spring (M,A,M)	1	7	10	30	25	27
Summer (J,J,A)	2	12	17	22	11	36
Fall (S,O,N)	0	4	8	26	29	33
Annual	1	6	10	25	27	31

North Bay

Season	Stability Class A	B	C	D-Day	D-Night	E&F
Winter (D,J,F)	0	2	7	22	41	28
Spring (M,A,M)	1	6	11	30	26	26
Summer (J,J,A)	1	10	16	28	15	30
Fall (S,O,N)	0	3	7	28	37	25
Annual	1	5	10	27	30	27

Specific features, such as the river valleys mentioned above, and the Great Lakes can be expected to enhance stability effects. The lake breeze effect commonly encountered within two km of the shorelines of these lakes, basically refers to the instrusion of cold stable air inland. Stronger lake breeze circulations occur when land and air temperature differentials are very great, causing the lake breeze effect to extend as far as 30 km inland. This situation, while possible, is not common. Lake breeze effects near the St. Lawrence River and Ottawa River can be experienced with less frequency due to the smaller bodies of water.

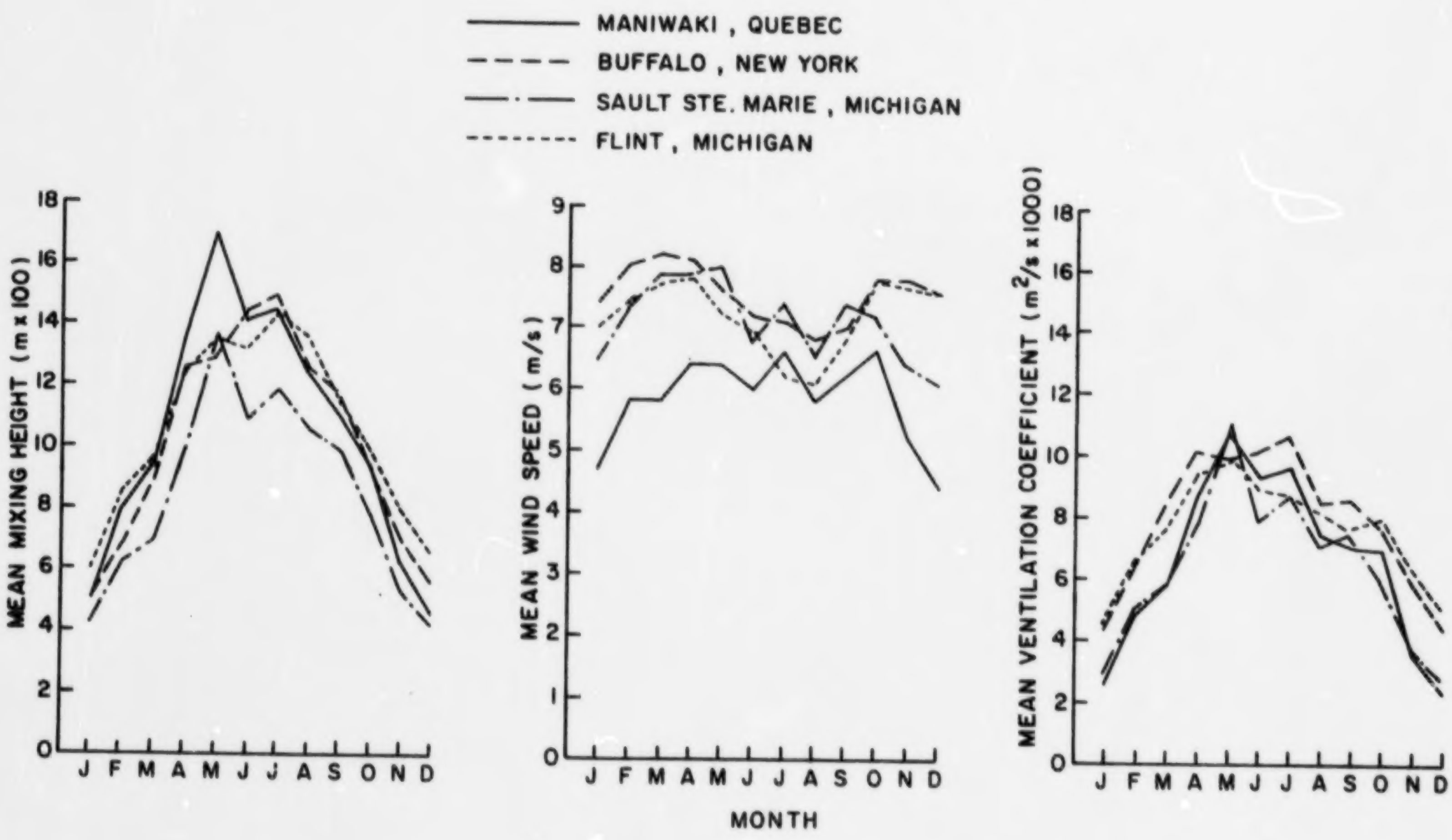
4.3 Mixing Heights

The mixing height concept is founded on the principle that when there is a temperature decrease with height increase in the atmosphere, heat from the earth's surface (radiational heating) will rise in eddies, resulting in convection, and vigorous vertical mixing (unstable conditions). The maximum extent of the vertical mixing layer occurs at the point where temperatures start to increase with height (stable conditions); i.e. where the effects of the surface radiational heating do not extend. Case A and B of Figure 1 portray unlimited or high mixing heights, whereas Case D illustrates the maximum extent of mixing, encountered in the early morning.

Ground-based mixing layers are common over mid-latitude land areas during the day and over cities at night. However, in rural areas at night they are often absent, being replaced by stable conditions. When considering air pollution episodes, it is important to know the maximum extent of vertical mixing which occurs during the day-time (Portelli, 1977).

There are no upper-air stations in the study area. However, relative mixing heights can be extrapolated for Southern Ontario by considering the four closest surrounding upper air stations. The stations from which data are available are as follows: Maniwaki, Quebec; Buffalo, New York; Flint, Michigan; Sault Ste. Marie, Michigan. Station locations and mean monthly maximum mixing heights have been plotted in Figure 6 to represent the approximate conditions for Southern Ontario. An annual average of approximately 1000 m can be expected.

FIG. 6 MONTHLY MEAN AFTERNOON MIXING HEIGHTS, WIND SPEEDS AVERAGED THROUGH THE MIXED LAYER AND VENTILATION COEFFICIENTS. 1965-1969



During the winter months, mean maximum afternoon mixing heights are approximately 600 m. By the summer months, mean maximum mixing heights attained in Southern Ontario will be close to 1400 m.

Mixing height frequency tables (Environment Canada, 1976), for 1966 to 1969 (most recent valid data set) indicating the ranges of maximum mixing heights versus wind speed and wind direction are available for Maniwaki, Buffalo, Flint and Sault Ste. Marie (Appendix 7). The results do not represent the actual mixing heights and meteorological conditions in Southern Ontario but are considered to be reliable estimates of the prevailing conditions.

Annual mixing heights of 800 to 1000 m occur most frequently in this region. During the summer and winter seasons mean mixing heights ranging from 1400 to 1600 m (summer maximum) and 400 to 600 m (winter maximum) occur most frequently. Nocturnal mixing heights in open-rural regions of Southern Ontario tend to be quite low and close to zero most of the time (Portelli, 1977).

Nocturnal mixing heights in urban regions formed as a result of urban heat island effects may be of the magnitude of 200 m. Pollutants are trapped within the 'heat island' boundaries by the extent of this relatively low mixed layer, increasing air pollution potential during the night hours in cities such as Toronto, Hamilton and Sarnia, as compared to rural areas. Hamilton experiences lake breeze effects and entrapment by topographical features, to combine with the effects of this nocturnal trapping, creating severe air pollution potential.

4.4 Mixing Layer Winds

Figure 6 also includes the mean monthly values of the mixing layer wind speed for the same four upper-air stations (Maniwaki, Buffalo, Flint and Sault Ste. Marie). Mean mixing layer wind speeds are not to be confused with synoptic or surface winds, since the mean mixing layer wind is calculated by averaging the wind speeds observed at a number of levels throughout the mixed layer. For Southern Ontario, a monthly average value of approximately 7 m/s is estimated. Mixing layer winds are strongest in the spring and autumn months. In the spring and autumn, rapid passages of frontal cyclones ensure high mean wind speeds. During the summer months, upper air circulations are weak and ill-defined, and mean mixing layer wind speeds are at a minimum for the year. In the winter, Southern Ontario is often under the influence of large cold anticyclones. The passage of intense frontal cyclones, however, causes mean wind speeds in the mixing layer to be high during these events. Therefore,mean winter values are close to the annual average (Shaw et al., 1972).

The most frequently occurring mixing layer wind speeds at all stations are 4.1 to 8.0 m/s, on an annual and seasonal basis. The most frequent direction of the mixing layer winds is 250° to 280° (i.e. westerly) for all seasons, for Southern Ontario (Appendix 7; Environment Canada, 1976).

4.5 Mixing Layer Ventilation Coefficients

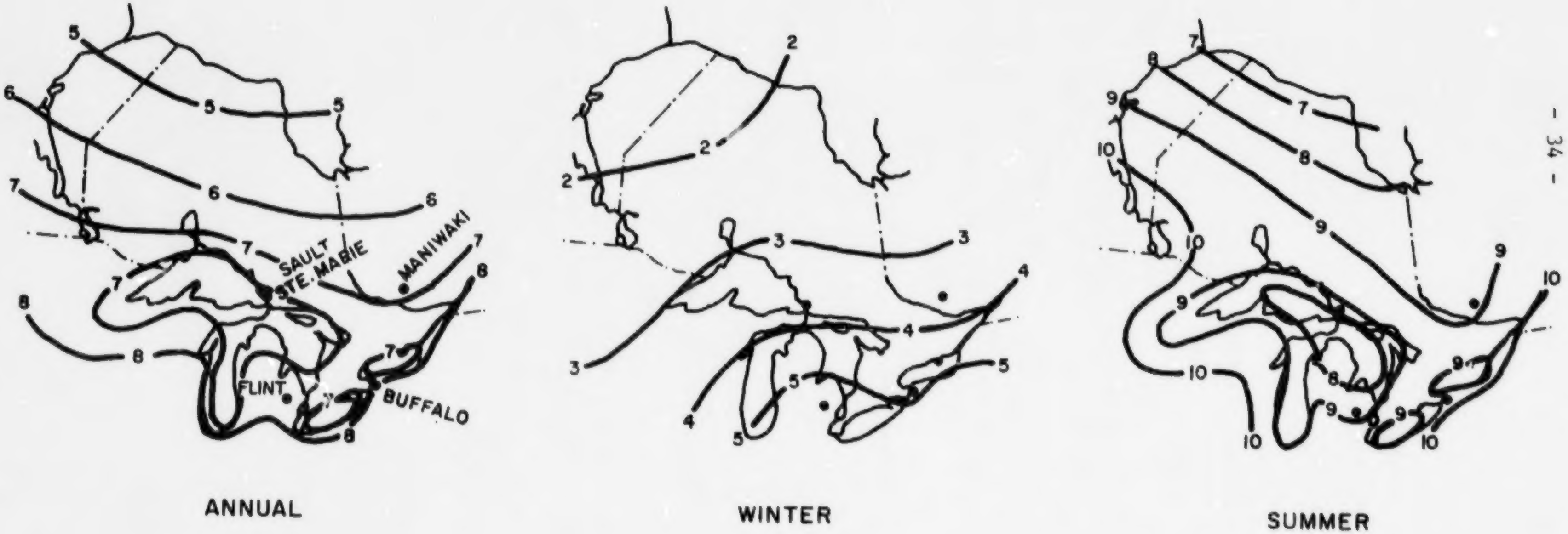
Maximum mixing depths cannot be considered as overall indices of air pollution potential but must be used in conjunction with other factors such as mean wind speed in the mixed layer. The product of the mixing height and the mean mixing layer wind speed is referred to as the "ventilation coefficient". It can be interpreted as a ventilation or dilution factor so that the greater the ventilation coefficient, the more capable the atmosphere is to disperse pollutants.

It has been suggested by the U.S. Air Pollution Forecast Program (Gross, 1970), that ventilation coefficients which do not exceed 6,000 m^2/s are considered indicative of high pollution potential. Figure 6 shows the mean monthly values of maximum ventilation coefficients for Maniwaki, Buffalo, Flint and Sault Ste. Marie. An approximate annual average of 7,200 m^2/s is estimated for Southern Ontario. The months of October, November, December, January, February and March have mean ventilation coefficient values less than 6,000 m^2/s inferring that mid-day pollution potential is high during these months, based on atmospheric conditions.

Isopleths of mean maximum (afternoon) ventilation coefficients for Southern Ontario, for the winter, summer and annual case are presented in Figure 7. Annually, values range from 7,000 m^2/s in the northern section of the region to 8,000 m^2/s in the southern sections. Winter values show the largest spatial variation, ranging from 3,000 m^2/s to 5,000 m^2/s from the north to the south. The winter values do not appear to be influenced by the Great Lakes. The summer isopleths, however, indicate slightly lower values (8,000 to 9,000 m/s), surrounding the Great Lakes, with values just greater than 9,000 m/s further inland and north. Mixing heights can be expected to be lower adjacent to and over the open Great Lakes due to a higher occurrence of stable conditions and it is this factor which could be held responsible for the lower ventilation coefficients around the Great Lakes.

From frequency tables for the occurrence of mixing layer wind speeds with various ranges of ventilation coefficients for the four upper air sites (Appendix 7), the most frequently occurring ventilation coefficients are in the greater than or equal to 11,100 m^2/s range annually, and in the summer months. During the winter, however, ventilation coefficients tend to be very high or very low at the four stations, with values either greater than or equal to 11,100 m^2/s or zero to 4,000 m^2/s. The probability of occurrence of ventilation coefficients less than or equal to 6,000 m^2/s occurs approximately 57, 49, 49 and 60 percent of the time annually in Maniwaki, Buffalo, Flint and Sault Ste. Marie respectively. During the summer months in Southern Ontario, the 6,000 m^2/s value is exceeded approximately 56 to 65 percent of the time, and 23 to 40 percent of the time in the winter, as a function of geographical location (Appendix 7).

FIG. 7 ISOPLETHS ($m^2 \cdot s^{-1} \times 1000$) OF MEAN MAXIMUM (AFTERNOON) VENTILATION COEFFICIENTS FOR SOUTHERN ONTARIO.


SAULT STE. MARIE
MANIWAKI
FLINT
BUFFALO
5
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7
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2
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4
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10

ANNUAL WINTER SUMMER

from : Portelli, 1977

5. CONCLUSIONS AND RECOMMENDATIONS

From the above discussion it can be seen that only relatively small climatic variations occur across Southern Ontario. The Great Lakes region typified by the Sarnia and Toronto data experiences a slightly more moderate climate, with warmer air temperatures, less incidence of frost, and less precipitation and fog than the inland and especially the more northern regions. Adequate precipitation frequency and amounts through all seasons ensure the regular washout of pollutants close to the source of emission.

Surface winds throughout Southern Ontario tend to be moderate (mean of 4.4 m/s) with constantly changing speeds and directions. As a result, poor dispersion conditions do not usually involve wind persistence as a major contributing factor. The winter season experiences the lowest maximum mixing heights (during the day), which combine with moderate upper air wind speeds to result in low ventilation coefficients (indicating high pollution potential). Atmospheric stability analyses, which account for both day and night situations, indicate that Southern Ontario does on average experience stable conditions every night of the year, conducive to poor dispersion conditions. However, during the summer months, stable conditions are recorded for a larger number of hours each night than during the winter. As discussed in preceding sections, local factors such as the Great Lakes and Niagara Escarpment, can interact with the prevailing meteorological conditions to create poor dispersion conditions in close proximity to these features, during the spring, summer and especially the fall.

On the basis of the climatological and meteorological considerations of this study it is concluded that most of Southern Ontario is characterized by atmospheric conditions which would provide proper dispersion of a pollutant emission to the atmosphere from a waste management facility. The following areas have constraints which may affect site suitability:

- any land within 2 km of the shoreline of the Great Lakes
- the region bordered by the Niagara Escarpment and Lake Ontario

- major urban centers.

The estimated spatial extent of influence of these factors in Southern Ontario is graphically defined in Figure 8 (in the pocket at the back of the report). The "lake breeze effect" classification encompasses the strip of land within approximately 2 km from the shorelines of the Great Lakes. The "urban heat island effect" is designated in the cities and larger towns of Southern Ontario. The "topographic effect" refers to the region where "trapping" of pollutants may occur, near the Niagara Escarpment. "Minor possible lake breeze effect" represents a strip of land 2 to 30 km from the shorelines of the Great Lakes and 10 km from the St. Lawrence and Ottawa River valleys. While the potential for poor dispersion is substantially less in this zone than in the area designated under the "lake breeze effect", there is still a higher than average potential for adverse dispersion conditions to prevail, as lake breeze circulations may reach more than 30 km inland (Hewson and Olsson, 1967). The remainder of the study area has no specific meteorological or topographical features conducive to abnormally poor dispersion conditions.

Assuming that the areas affected by these three factors are avoided, high pollution potential from a possible facility could be experienced approximately 23 to 31 percent of the time annually based on stability (see Section 4.2). This figure reflects the 26 to 36 percent potential value for the summer, which is relatively high due to strong inversions experienced during summer nights, and the winter value of 17 to 28 percent which is influenced by stronger surface winds in the winter. Thus the atmosphere appears to have a higher dispersive capacity on a 24-hour basis in the winter, based on the above analysis. However, the actual mixed layer through which mixing takes place is lowest in the winter. The ventilation coefficient accounts for these factors at mid-day only, indicating that annually, potential pollution (i.e., relatively poor dispersion) during the mid-day period can occur approximately 49 to 60 percent of the time. On a seasonal basis, such conditions can occur 35 to 44 percent of the time during summer and 60 to 77 percent of the time during winter. It is important to note that the word 'potential' means conditions that can develop. The potential value is considered to be only generally applicable to the rural, inland regions of Southern Ontario, as the upper air meteorological data which is available does not permit resolution on a finer scale. As well, the relatively short duration of consistent meteorological conditions ensures that the high pollution potentials cited here would not create significant problems in rural, inland regions. Other climatological information and first-hand knowledge of the area confirms that relatively similar conditions do prevail across this area.

The designations provided here can be used in conjunction with the results of other background studies to identify one or more candidate regions. At that time more site-specific studies of the potential impact of the proposed facility on local air quality should be undertaken. These should include:

- a detailed inventory of all existing sources likely to emit the same pollutants as the waste management facility
- preparation of a projected emission inventory for the proposed facilities based upon data available from the operation of similar waste disposal facilities in other jurisdictions
- an in-depth review of all existing air quality and meteorological data specific to the proposed area(s)
- establishment of a baseline air quality and meteorological monitoring program to operate for at least one year prior to construction.

The objectives of the proposed baseline air quality and meteorological monitoring program will be:

1. to define any irregularities in the local climate and meteorology and to confirm the general conclusions of this study on a more local scale
2. to define prevailing air quality and meteorological conditions on a local basis.

The design of the monitoring program should take into account the specific nature and features of the candidate site. All Provincial Air Quality Criteria pollutants should be monitored and, in addition, special attention should be given to the collection of samples to be analyzed for specific compounds which may be of future concern. Meteorological monitoring should include upper air meteorological measurements a minimum of two times daily, as well as monitors to record wind speed and direction, air temperatures and precipitation. The availability of relevant parameters, both air quality and meteorological, from other ongoing surveys in the area would be considered in the detailed design of the survey.

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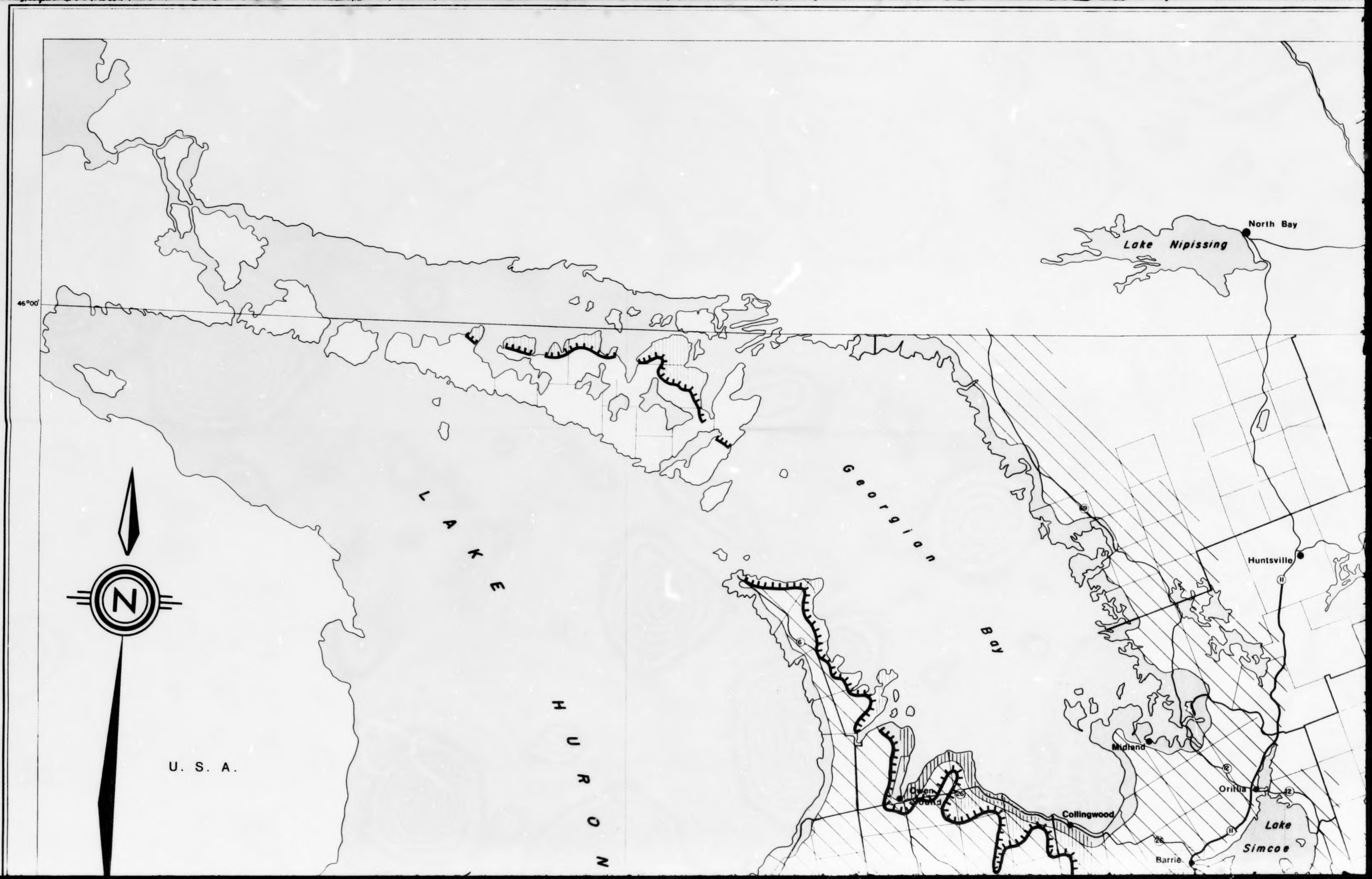
FIGURE 8. Estimated Boundaries of Meteorological Influences on Dispersion in Southern Ontario (see back pocket)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Collingwood
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Barrie
Lake Simcoe

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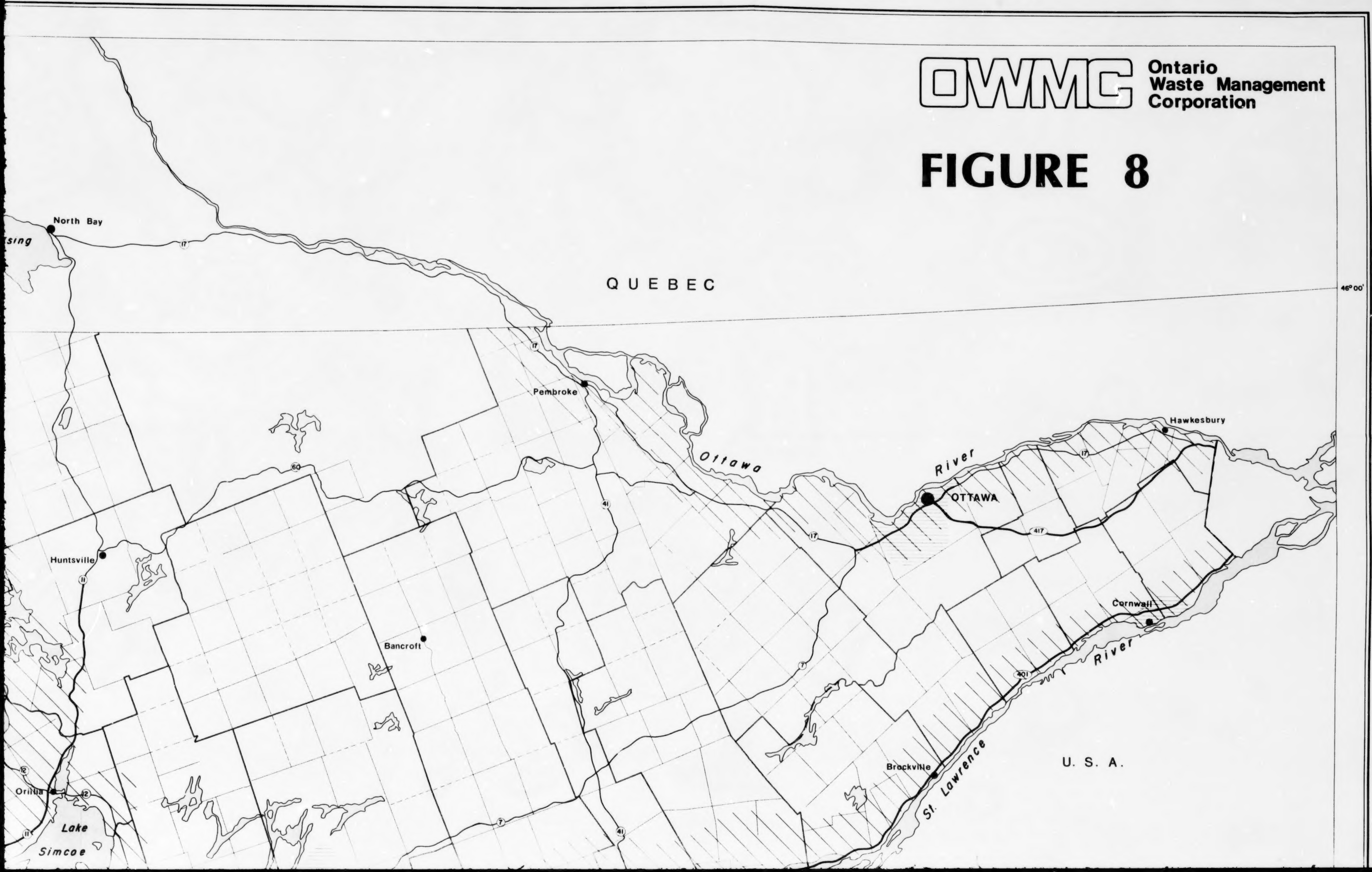
Corporation

FIGURE 8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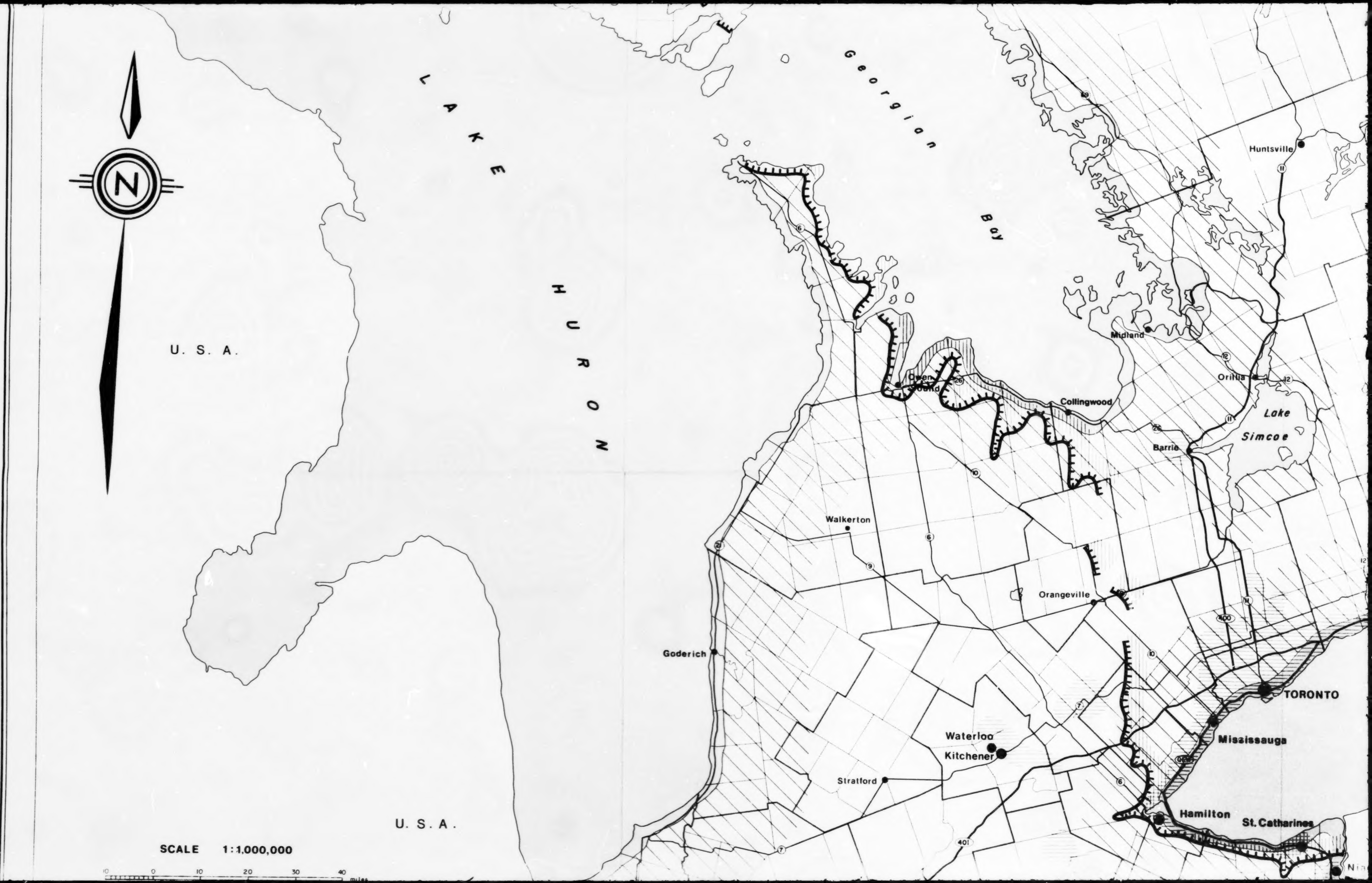
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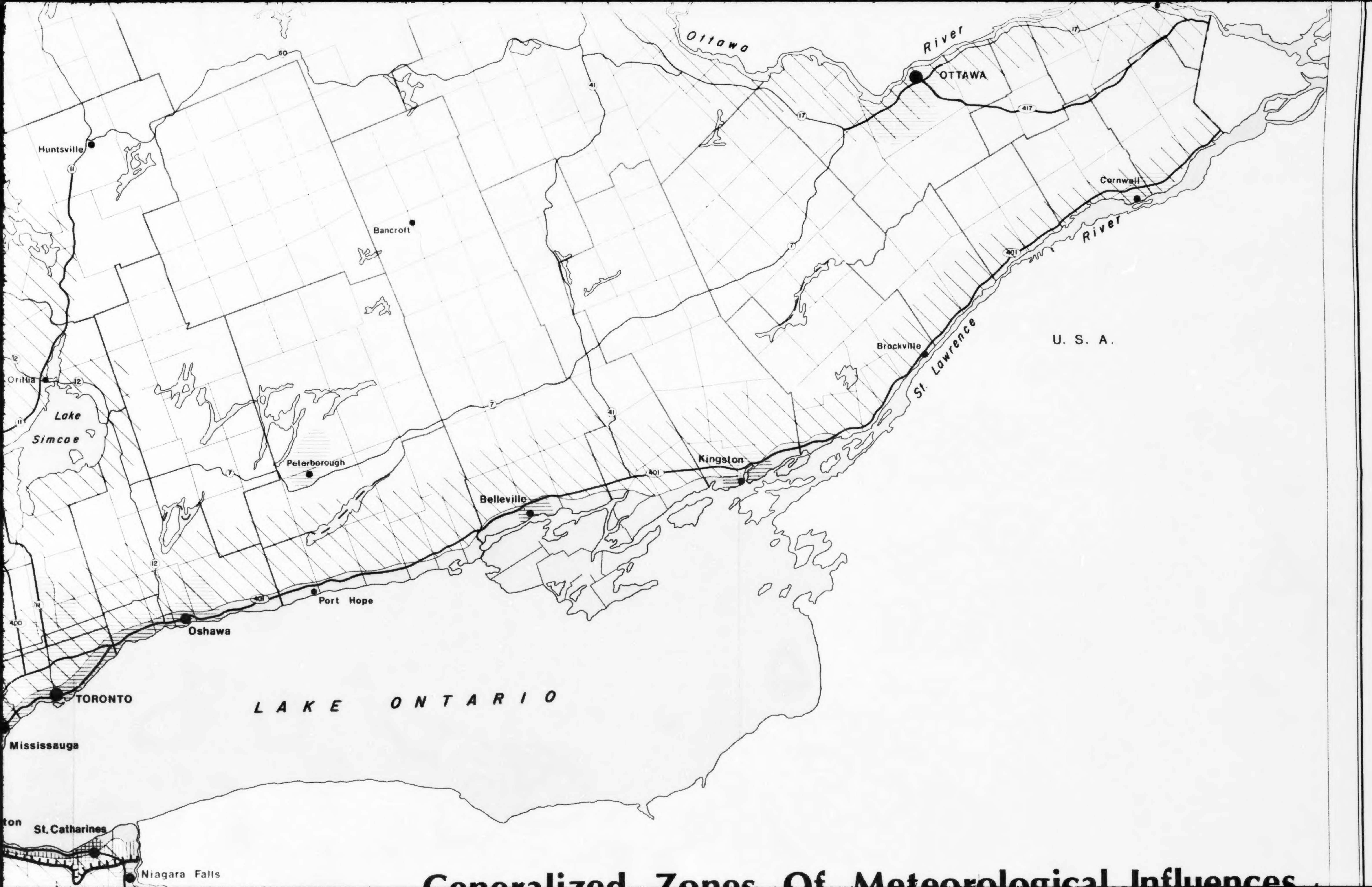
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Bancroft
Cornwall
U. S. A.
Brockville
St. Lawrence River
Orillia
Lake Simcoe
Peterborough
Kingston
Belleville
Port Hope
Oshawa
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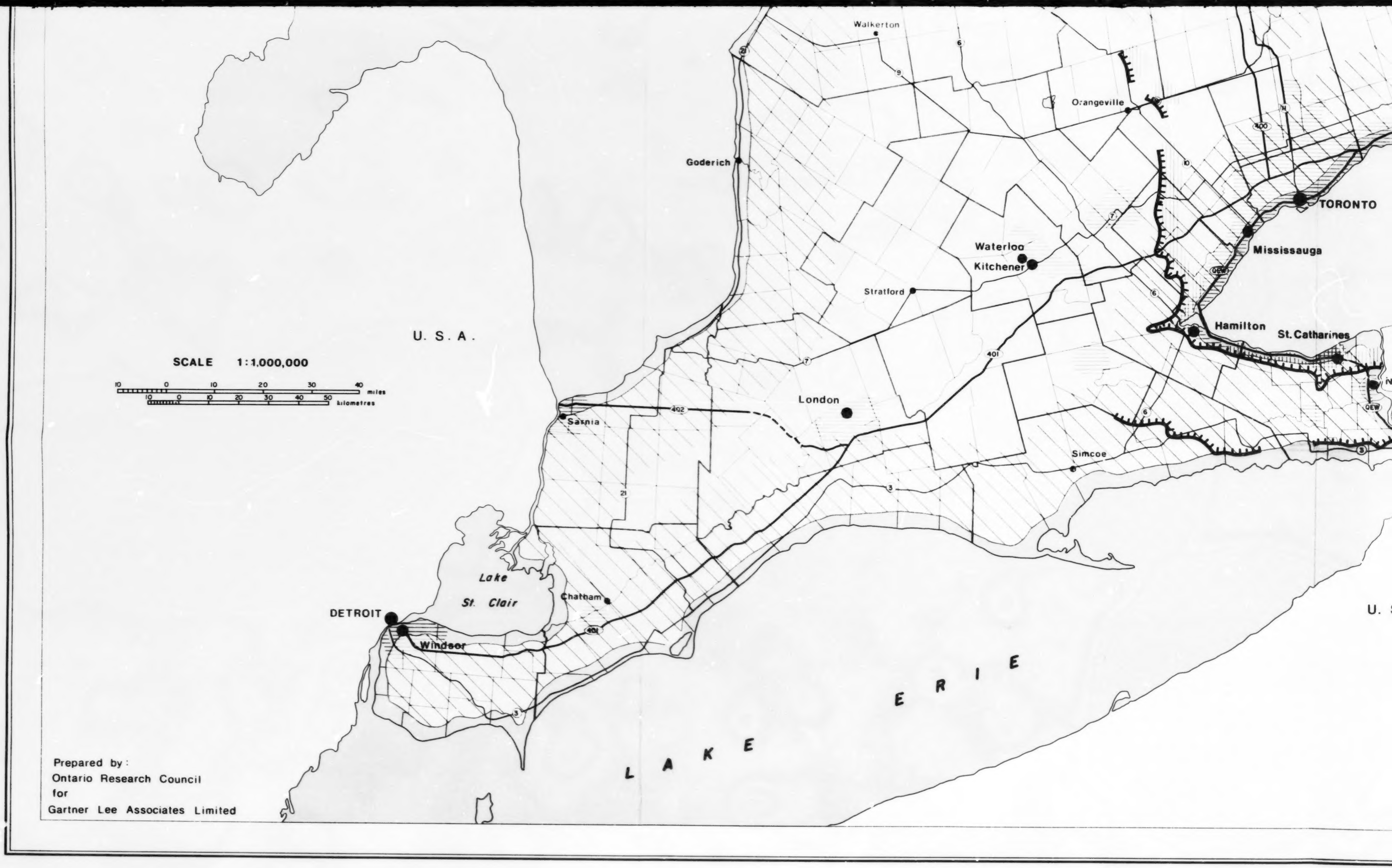
Generalized Zones Of Meteorological Influences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Simcoe
Lake St. Clair
Chatham
DETROIT
Windsor
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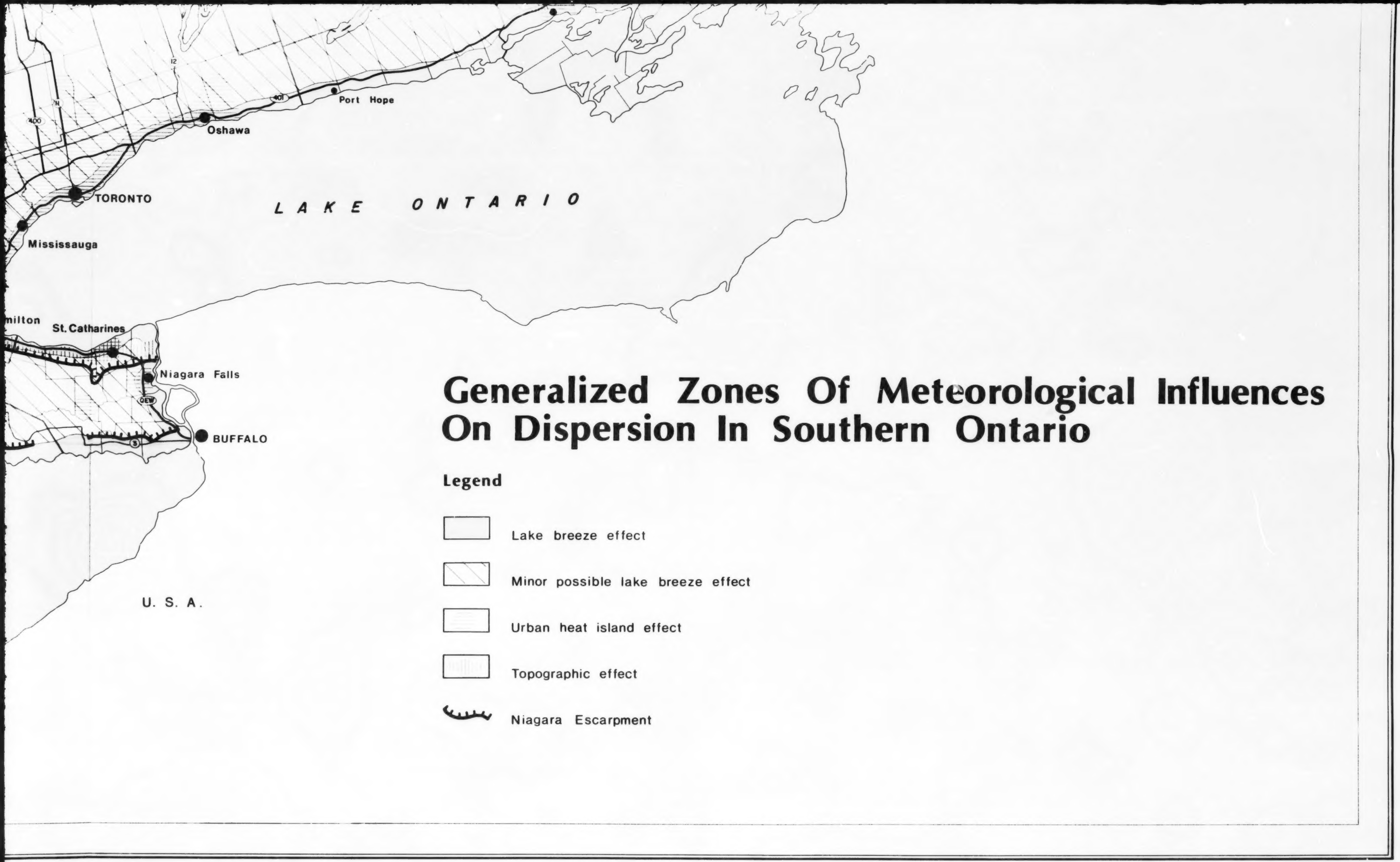

Generalized Zones Of Meteorological Influences On Dispersion In Southern Ontario

Legend

- ▭ Lake breeze effect
- ▨ Minor possible lake breeze effect
- ▤ Urban heat island effect
- ▥ Topographic effect
- Niagara Escarpment

Port Hope
Oshawa
TORONTO
LAKE ONTARIO
Mississauga
milton
St. Catharines
Niagara Falls
BUFFALO
U. S. A.
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4

Volume

2

OWMC

Ontario Waste Management Corporation

FINAL REPORT

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FOR

GARTNER LEE ASSOCIATES LIMITED

PROJECT NO. 82-1007

SEPTEMBER, 1982

FINAL REPORT
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VOLUME 2 - TECHNICAL APPENDICES

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Department of Environmental Chemistry

September 2, 1982

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APPENDIX 1

AIR TEMPERATURES (1951 - 1980)

FIG. 1.1 AIR TEMPERATURES
(1951-1980)

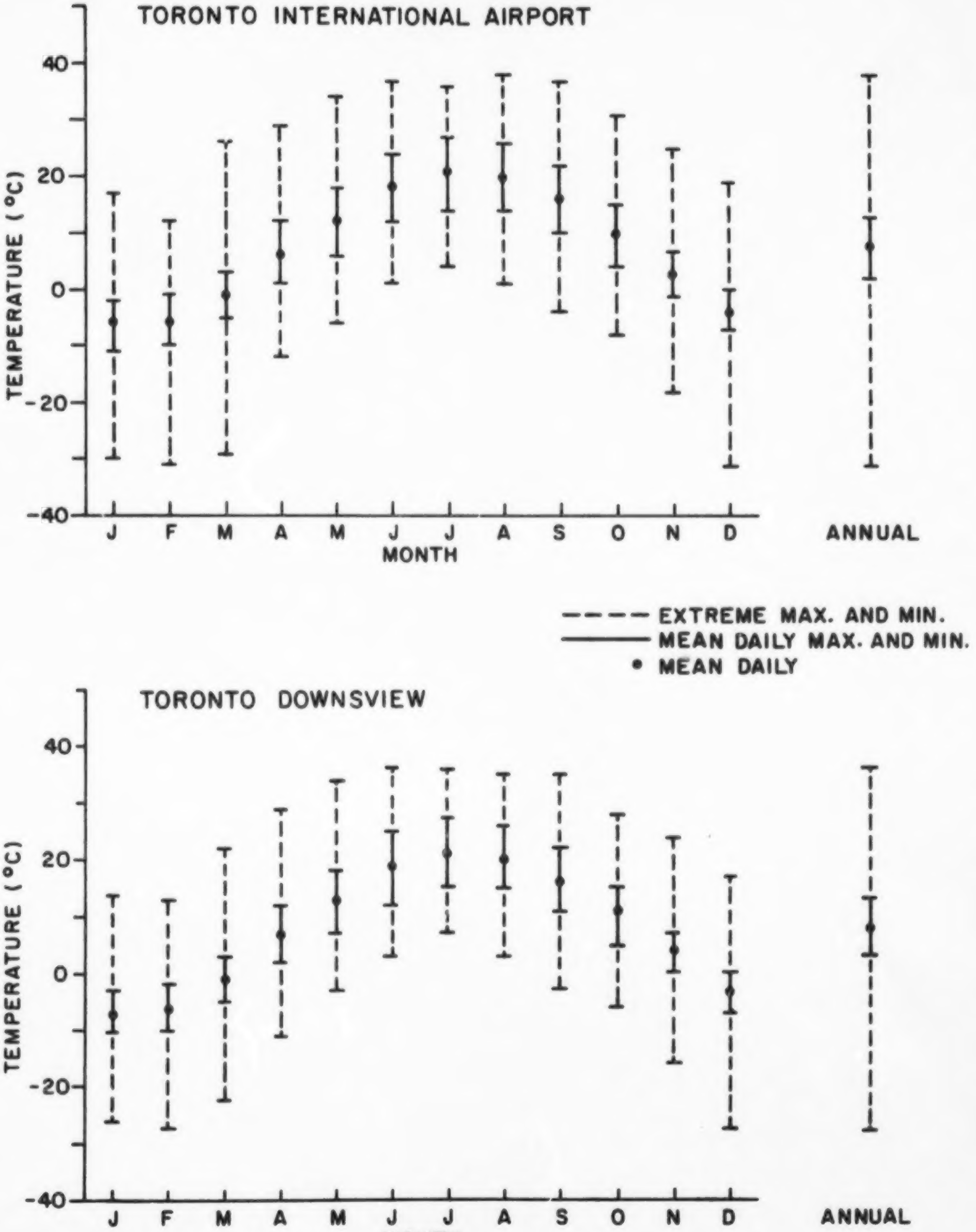


FIG. 1.2 AIR TEMPERATURES (1951-1980)

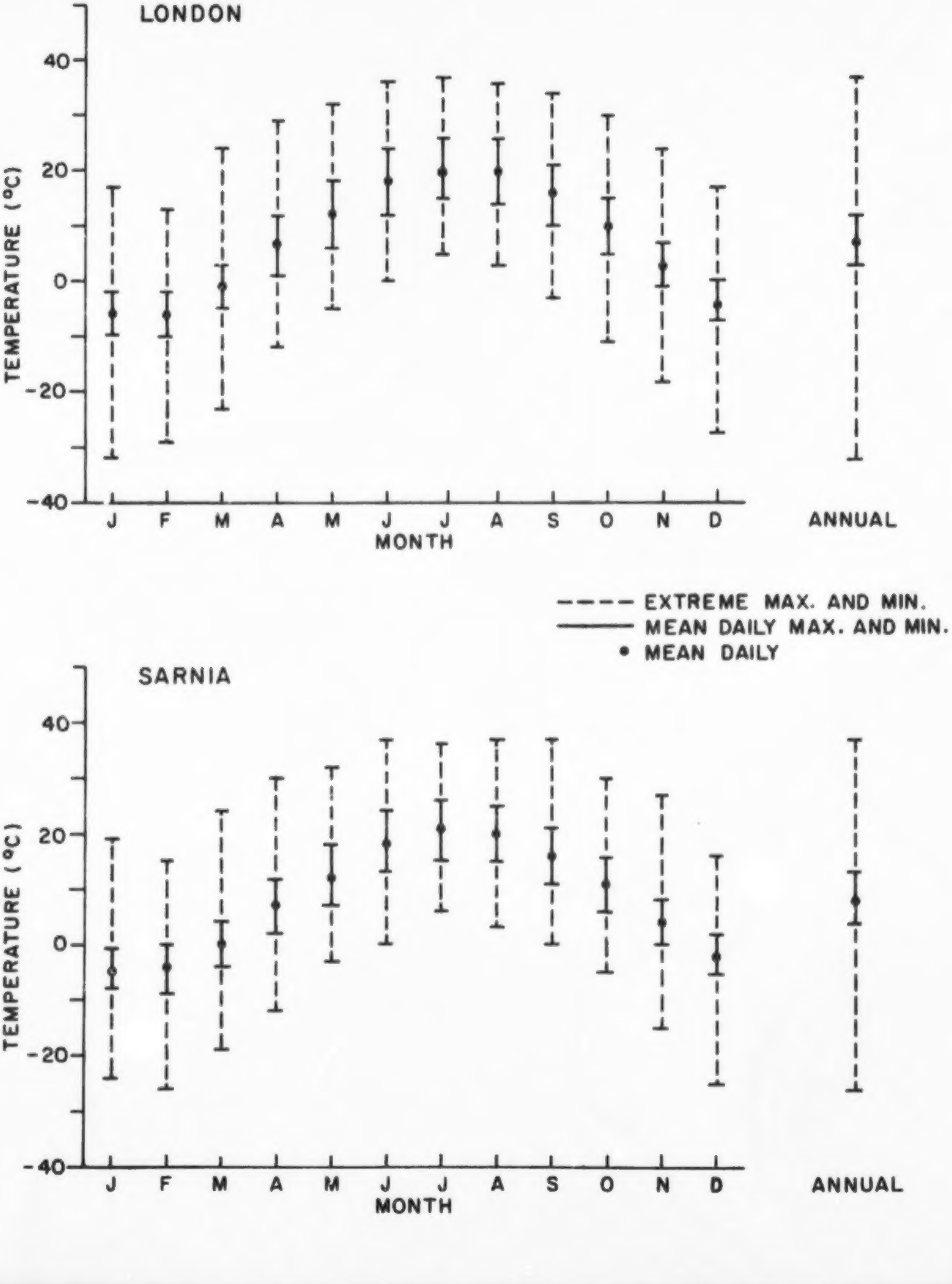


FIG. 1.3 AIR TEMPERATURES
(1951 - 1980)

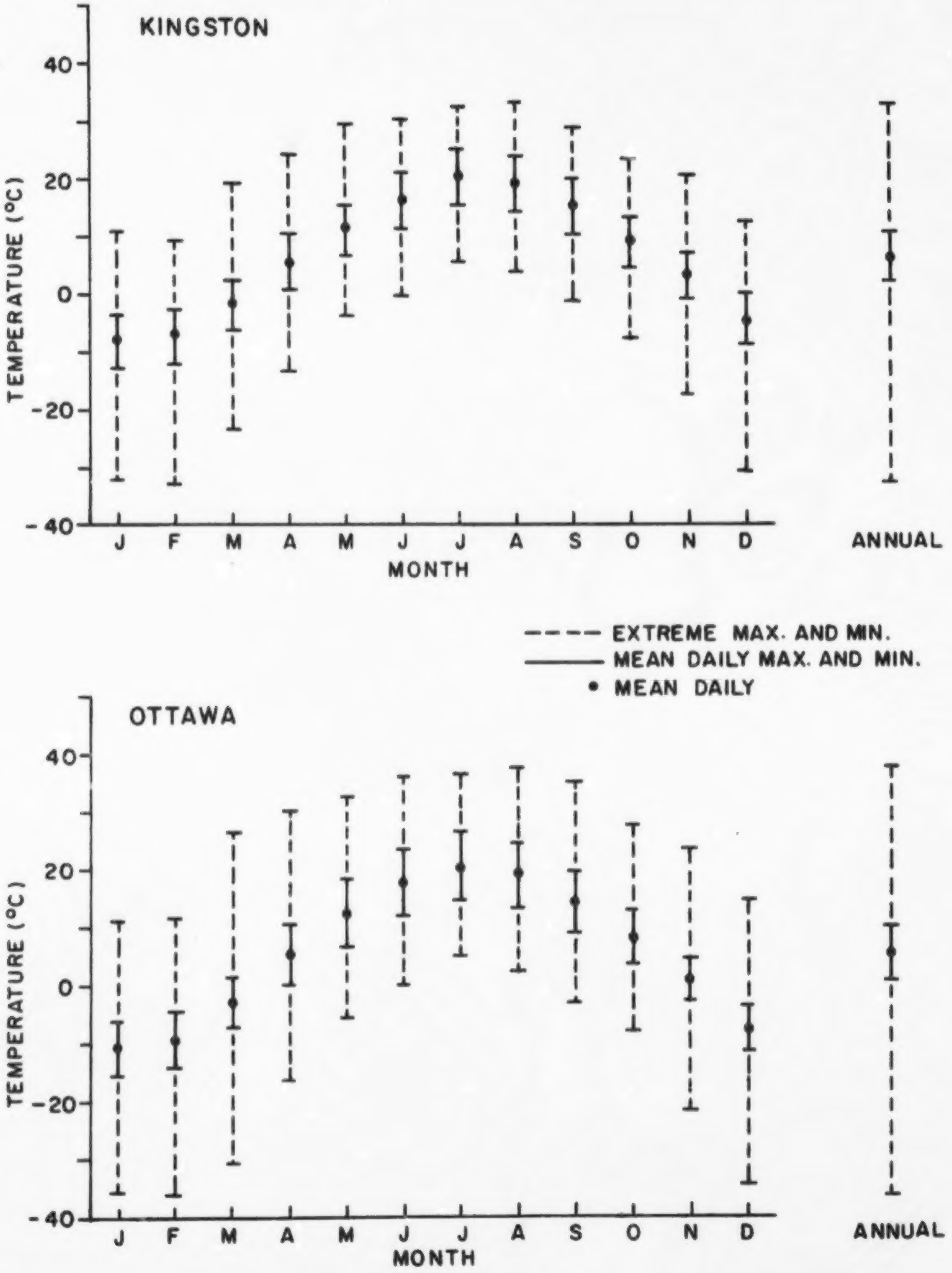
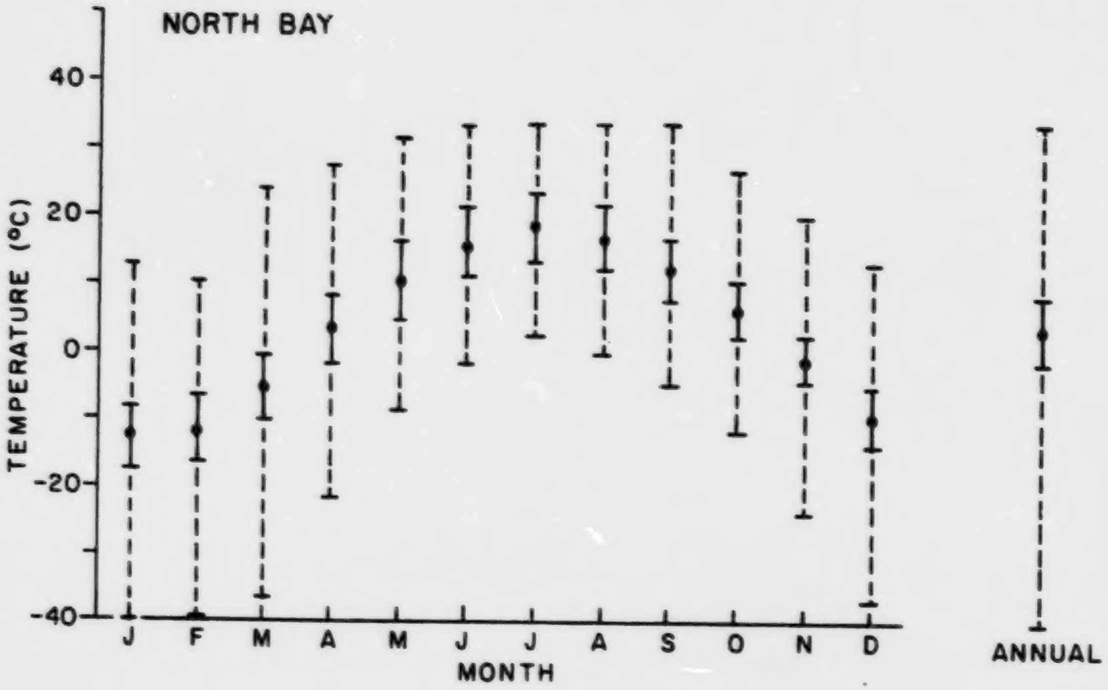


FIG. 1.4 AIR TEMPERATURES (1951-1980)



- - - - EXTREME MAX. AND MIN.
—— MEAN DAILY MAX. AND MIN.
• MEAN DAILY

APPENDIX 2

FROST DAYS PER MONTH (1941 - 1970)

FIG. 2.1 FROST DAYS PER MONTH

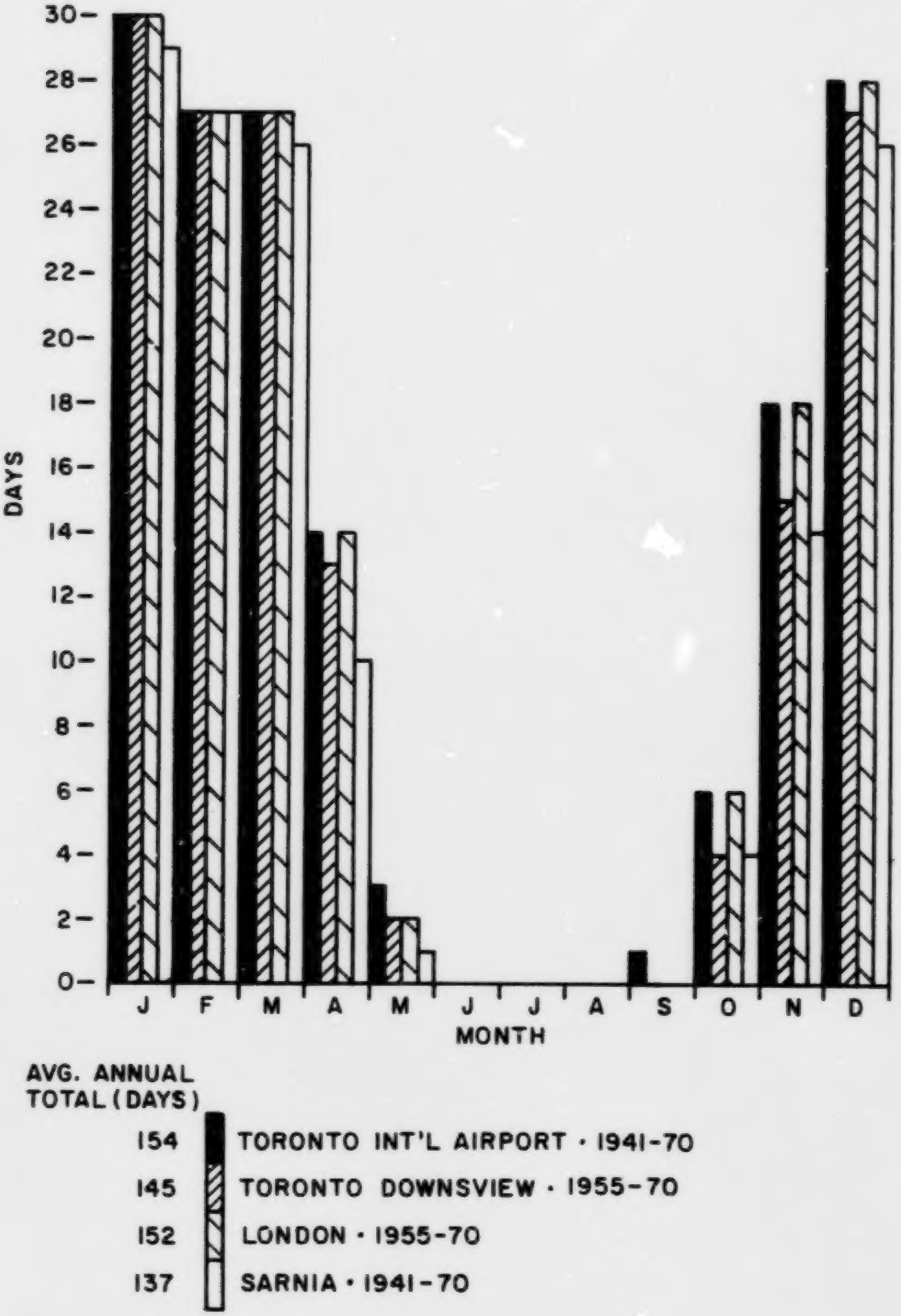
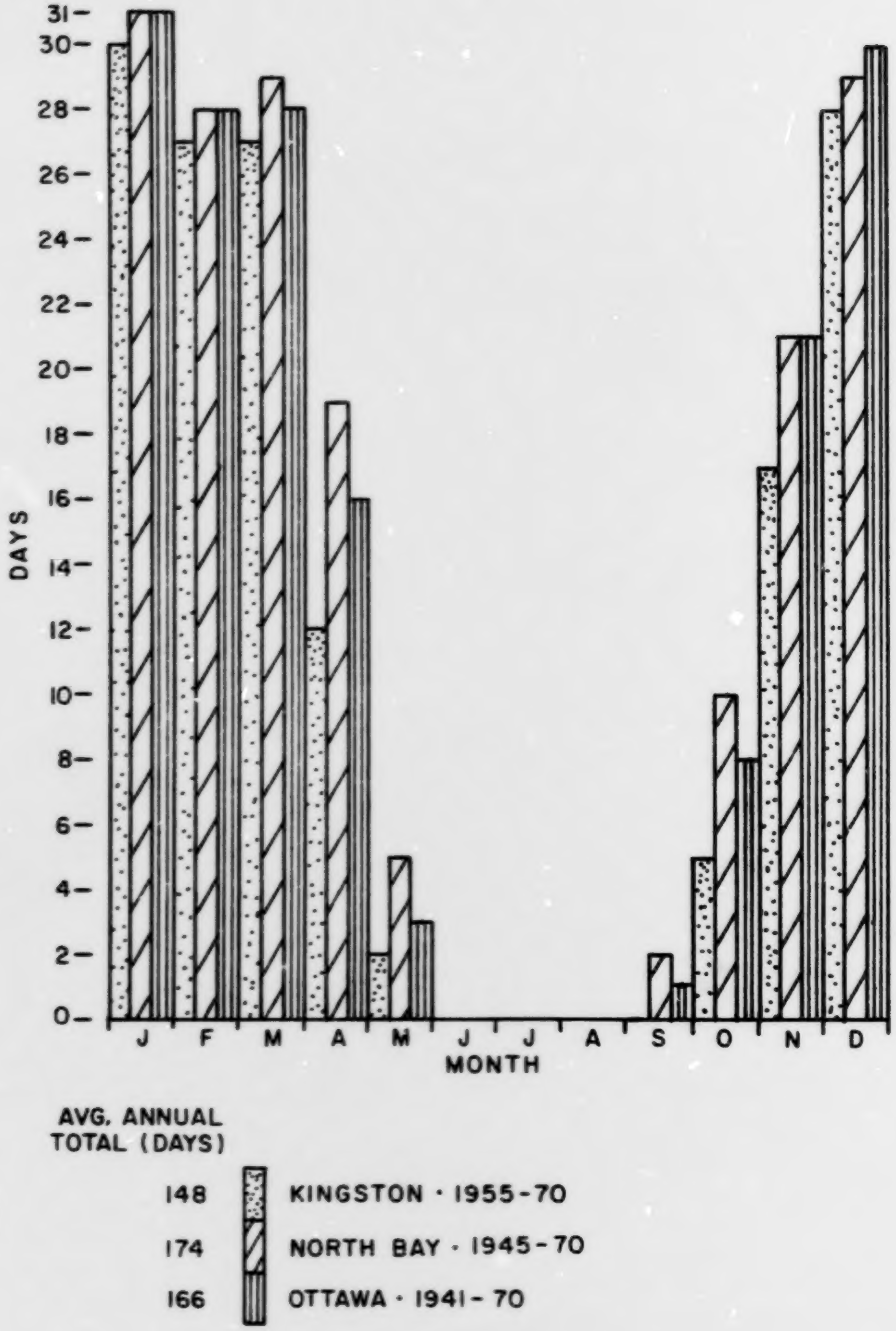


FIG. 2.2 FROST DAYS PER MONTH



APPENDIX 3

PRECIPITATION (1951 - 1980)

FIG. 3.1 PRECIPITATION

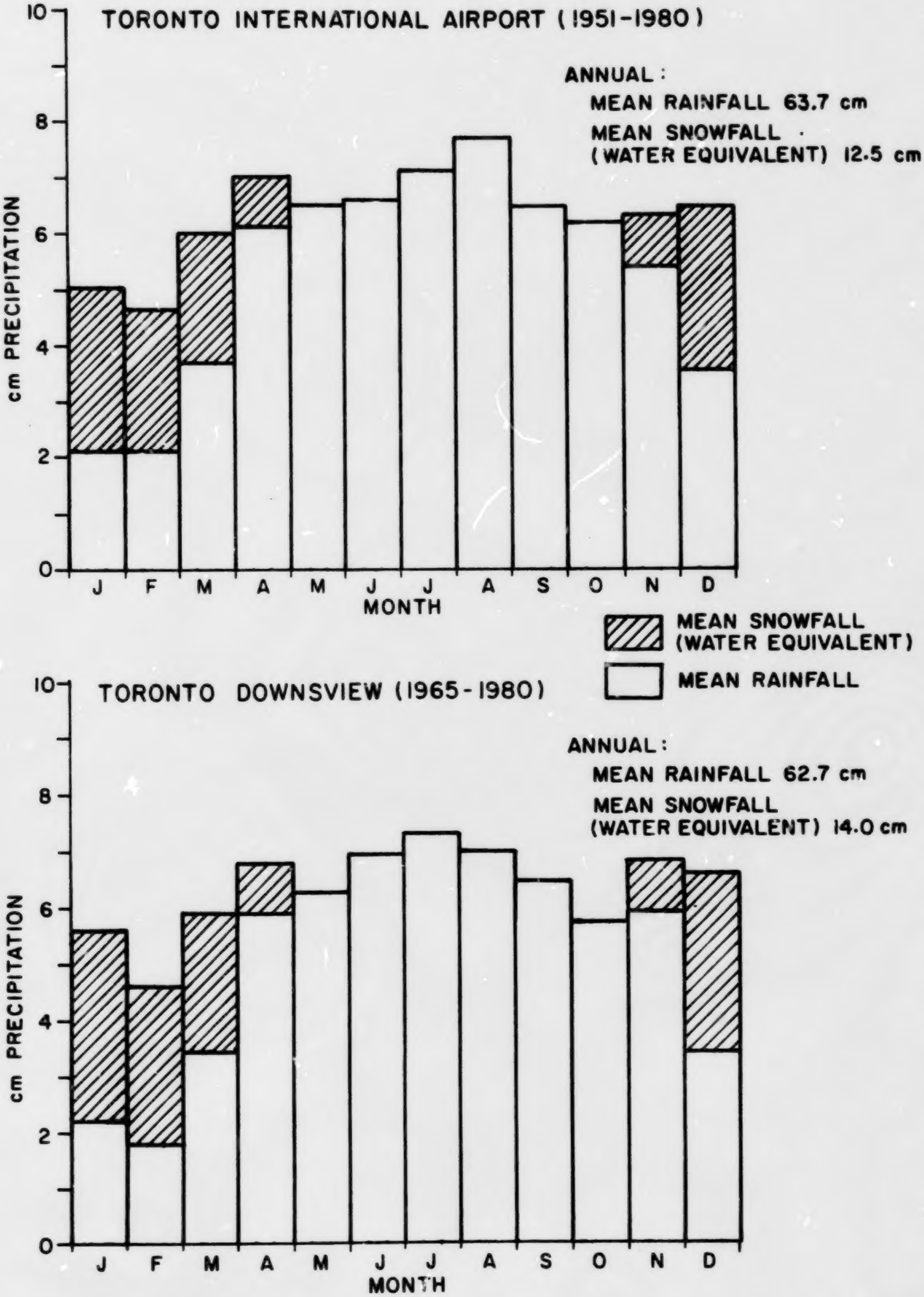
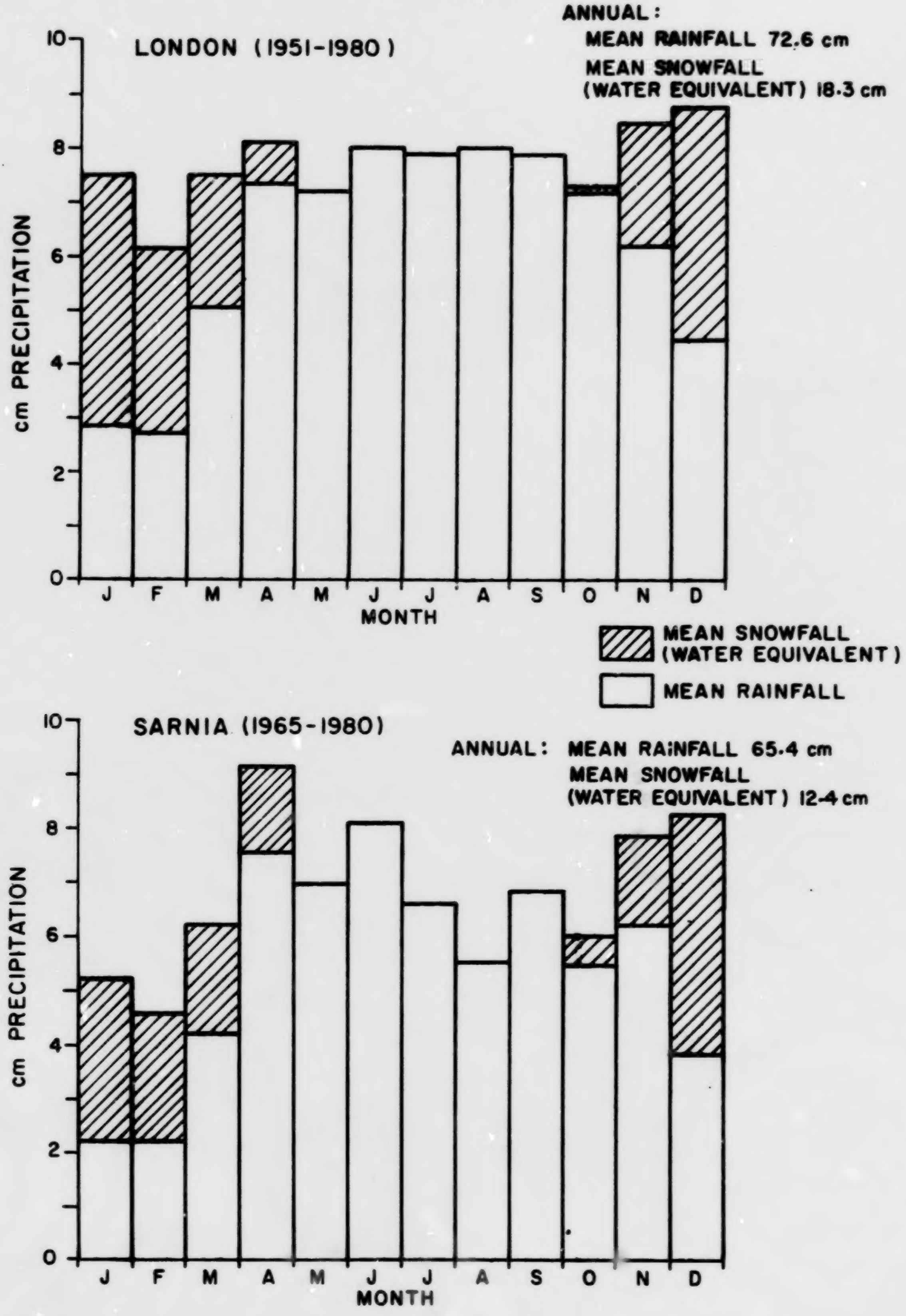


FIG. 3.2 PRECIPITATION



LONDON (1951-1980)

ANNUAL:
MEAN RAINFALL 72.6 cm
MEAN SNOWFALL (WATER EQUIVALENT) 18.3 cm

SARNIA (1965-1980)

ANNUAL: MEAN RAINFALL 65.4 cm
MEAN SNOWFALL (WATER EQUIVALENT) 12.4 cm

FIG. 3.3 PRECIPITATION

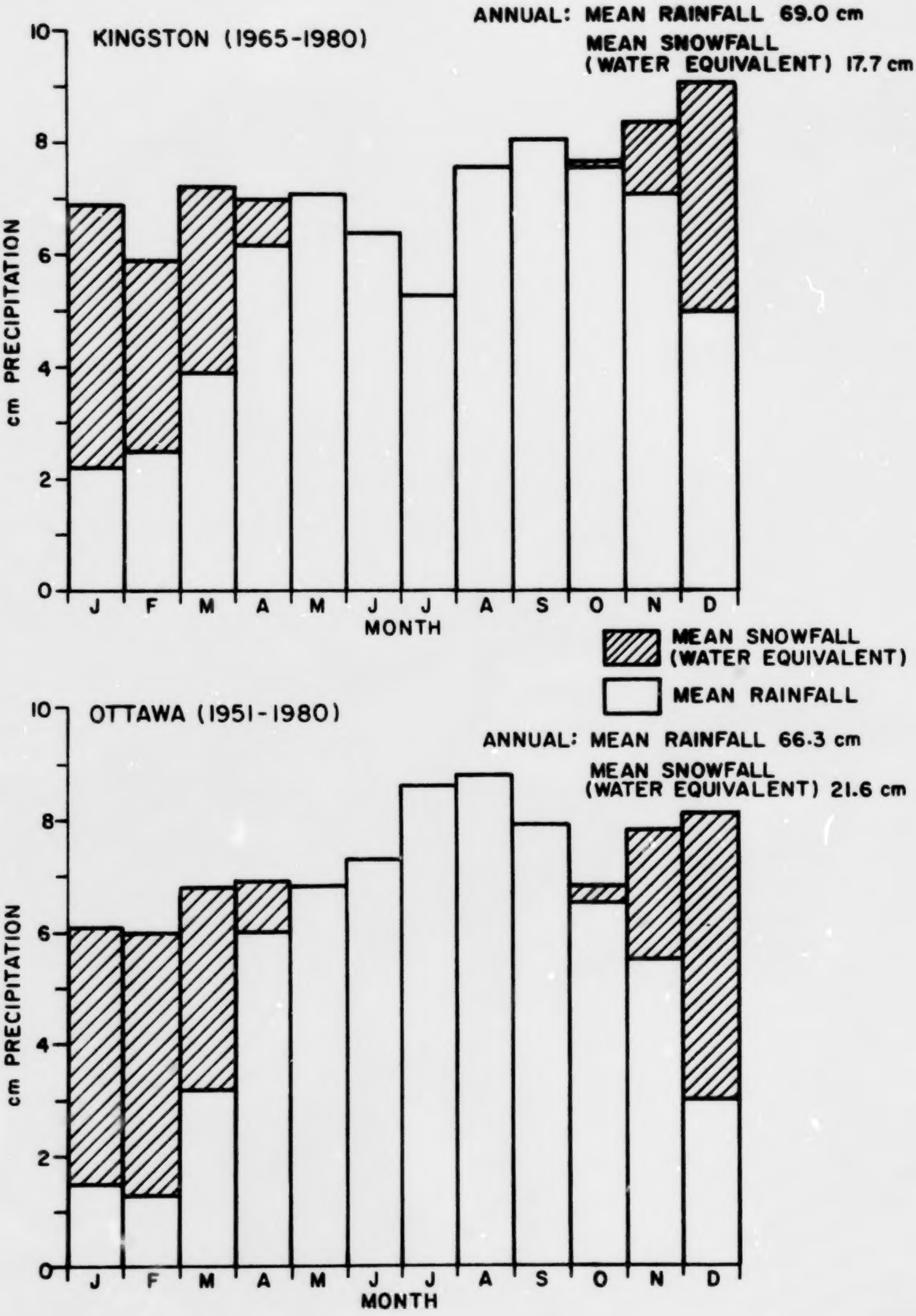
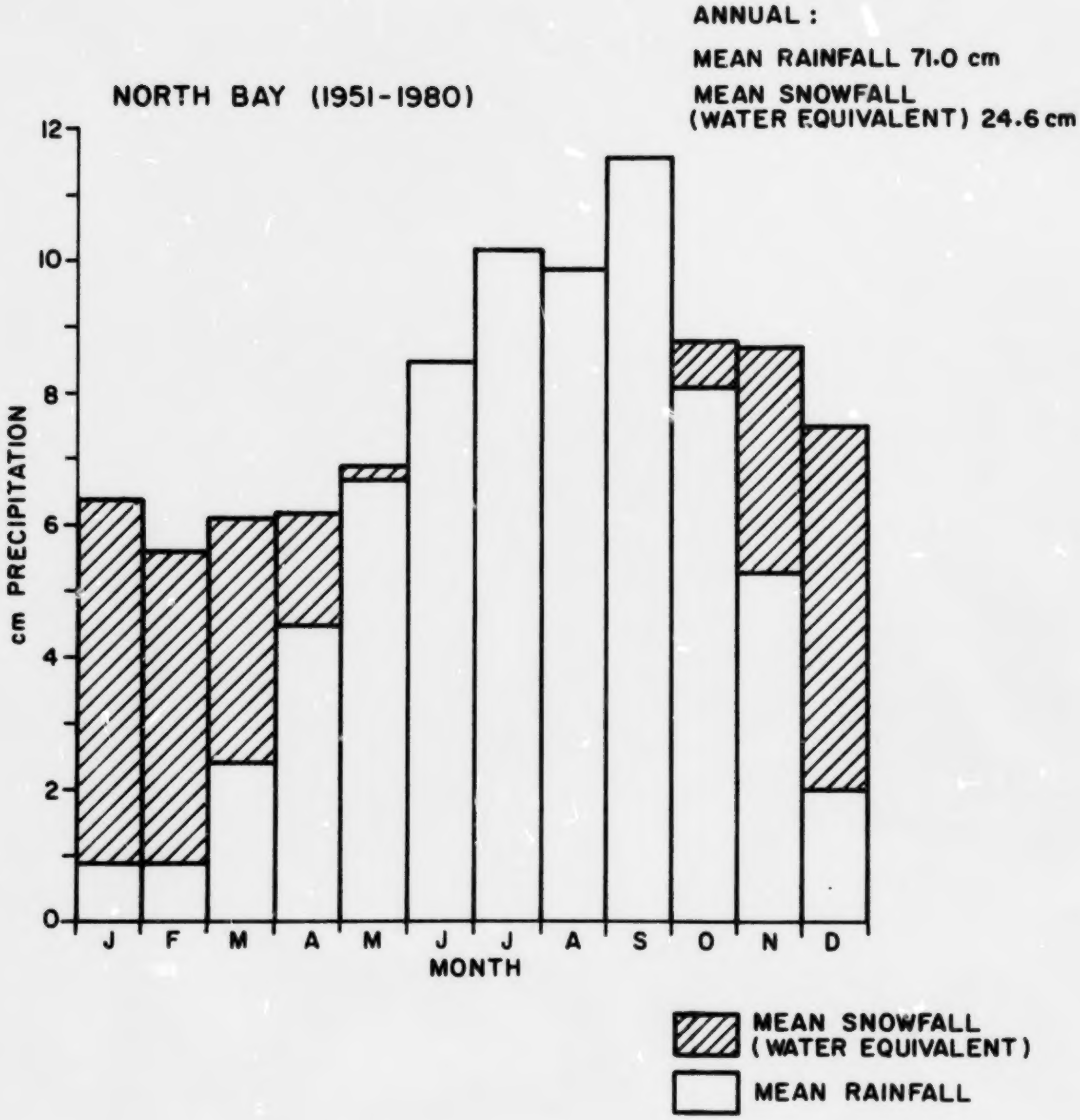


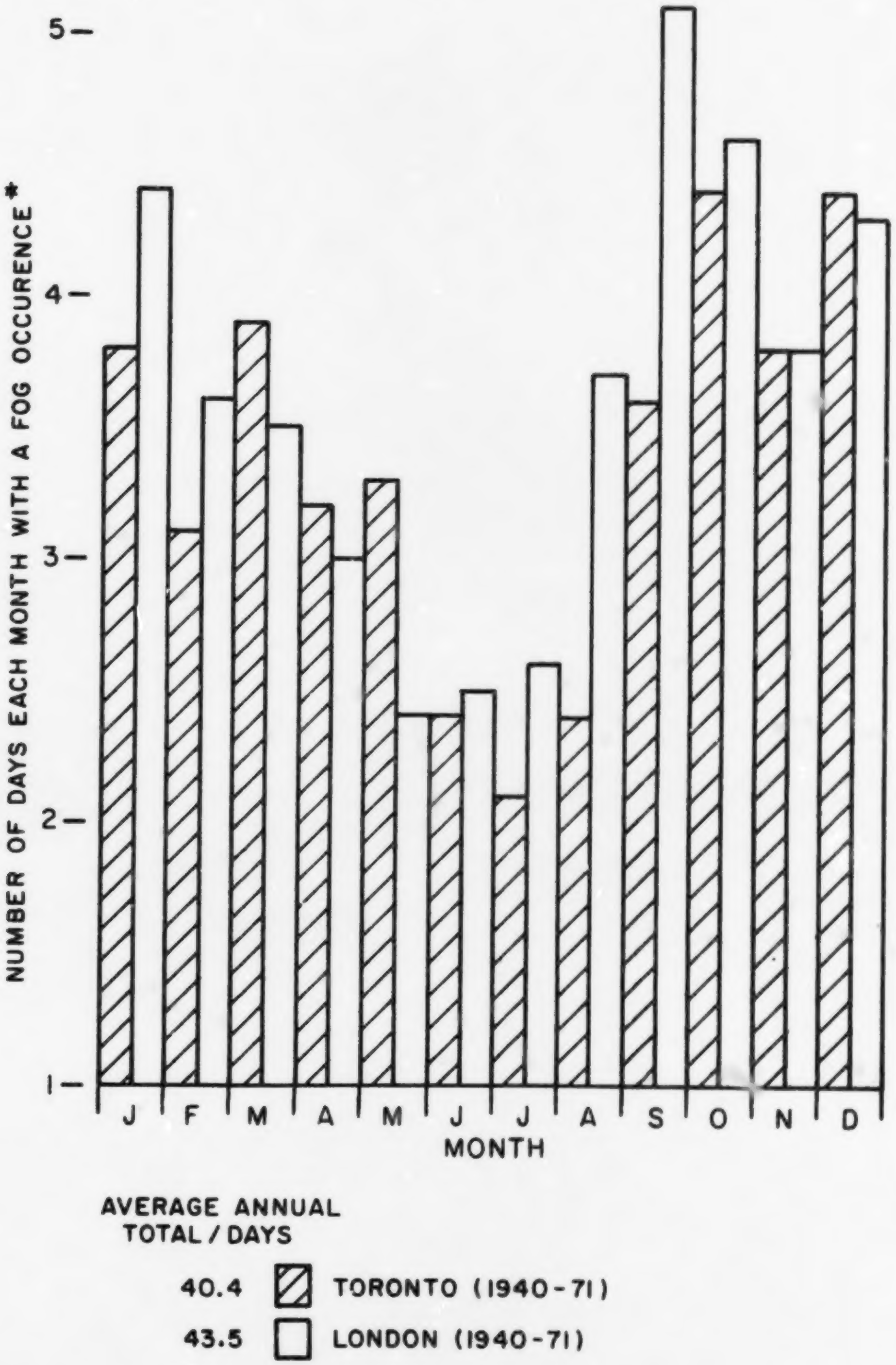
FIG. 3.4 PRECIPITATION



APPENDIX 4

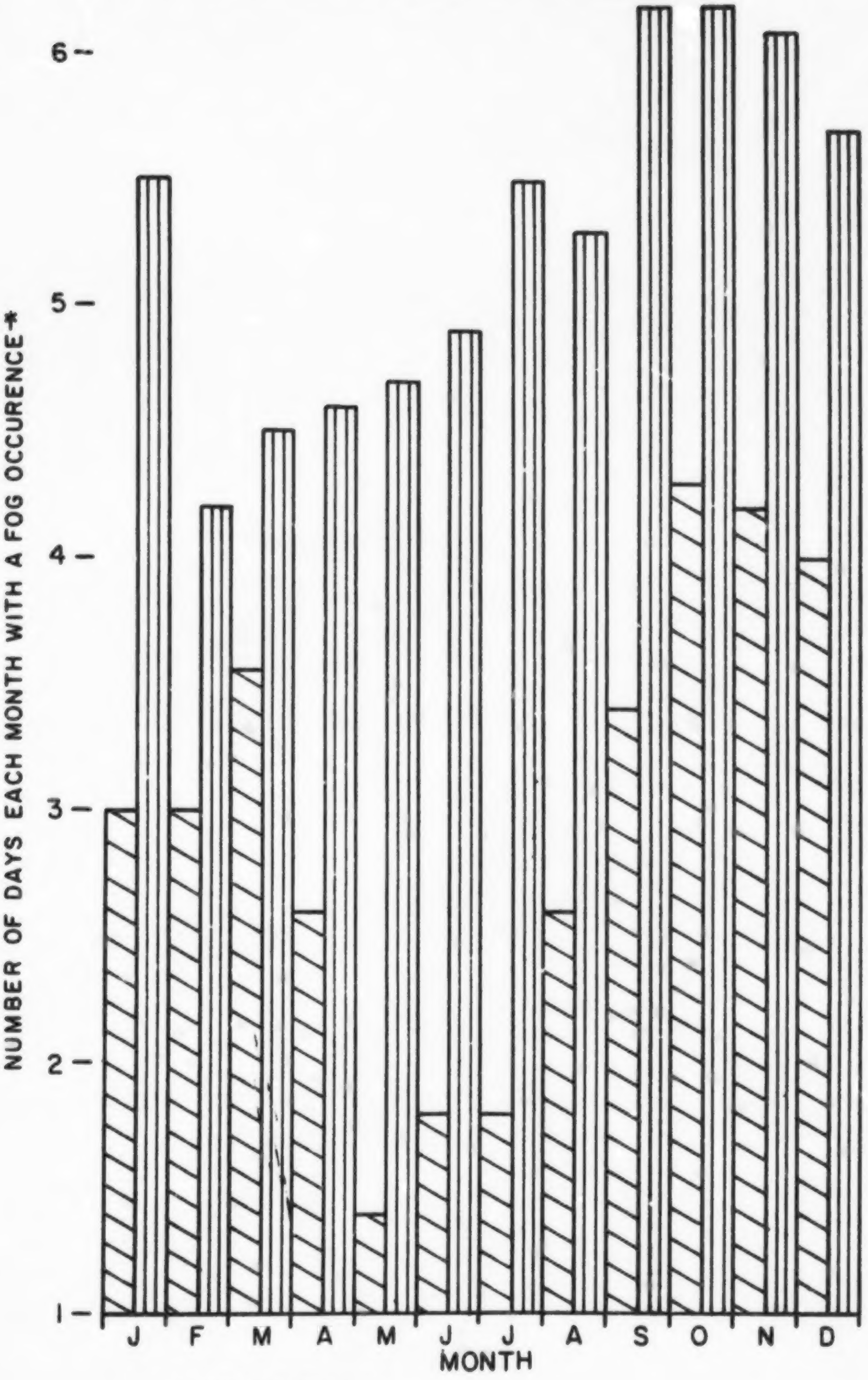
FOG DAYS PER MONTH (1940 - 1971)

FIGURE 4.1 FOG DAYS PER MONTH



* LIMITED VISIBILITY TO LESS THAN 1 km

FIGURE 4.2 FOG DAYS PER MONTH



AVERAGE ANNUAL TOTAL/DAYS

35.4 ▧ OTTAWA (1940-1971)

63.4 ▥ NORTH BAY (1940-1971)

* LIMITED VISIBILITY TO LESS THAN 1 km

APPENDIX 5

MEAN WIND SPEEDS (ALL DIRECTIONS) FOR SOUTHERN ONTARIO STATIONS

FIG. 5.1 MEAN WIND SPEEDS (ALL DIRECTIONS) FOR SOUTHERN ONTARIO STATIONS.

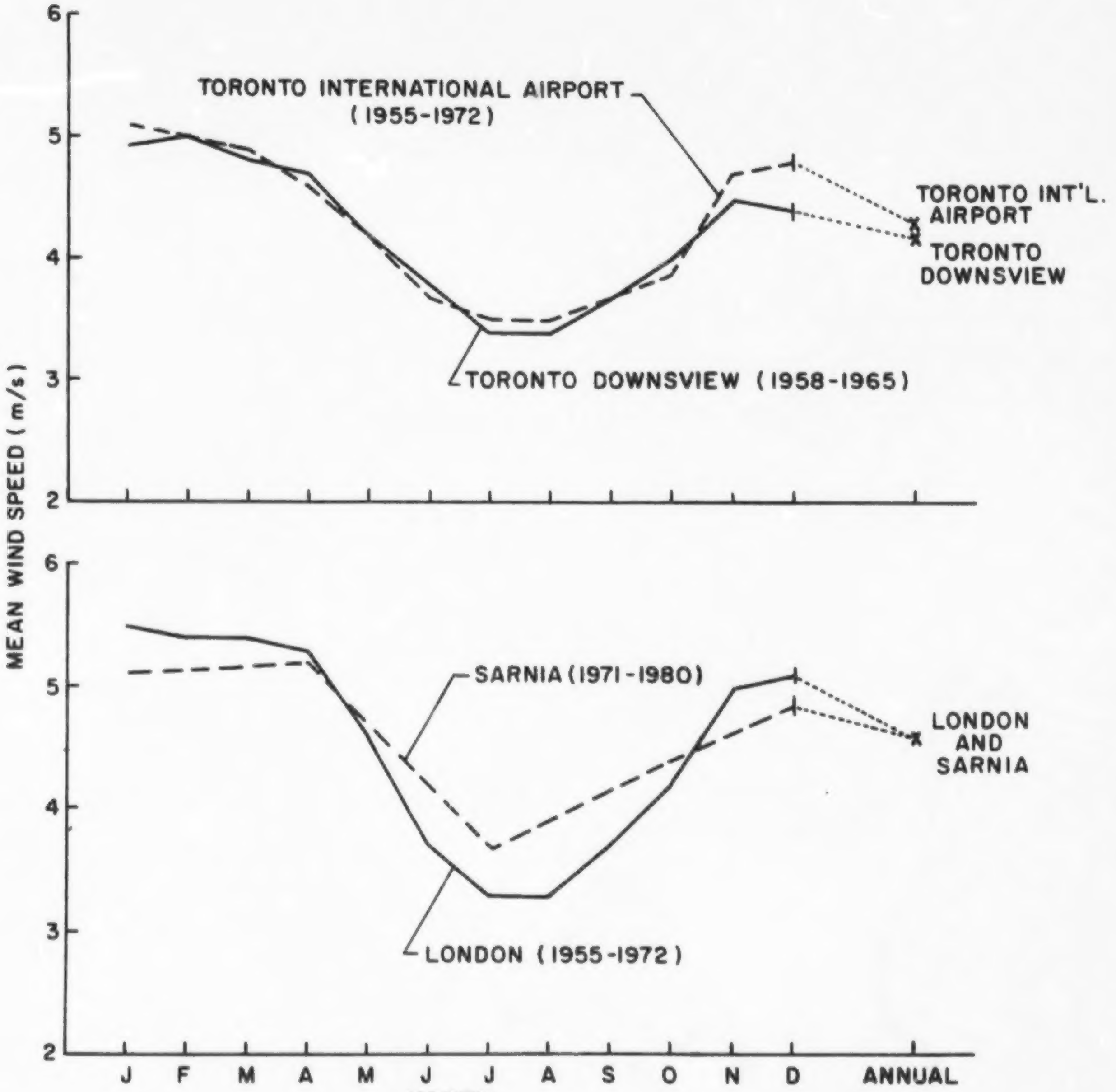


FIG. 5.2 MEAN WIND SPEEDS (ALL DIRECTIONS) FOR SOUTHERN ONTARIO STATIONS.

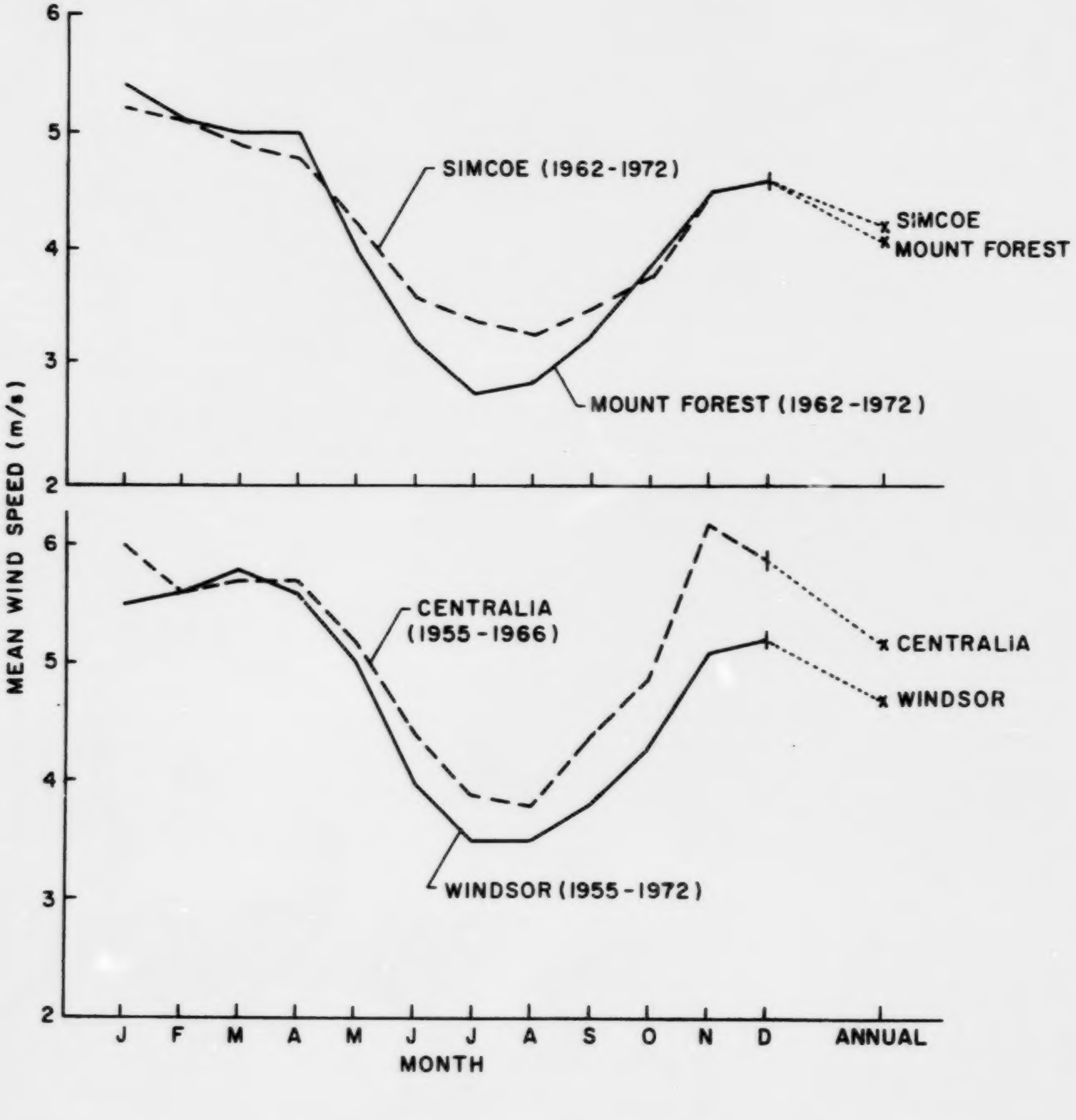


FIG. 5.3 MEAN WIND SPEEDS (ALL DIRECTIONS) FOR SOUTHERN ONTARIO STATIONS.

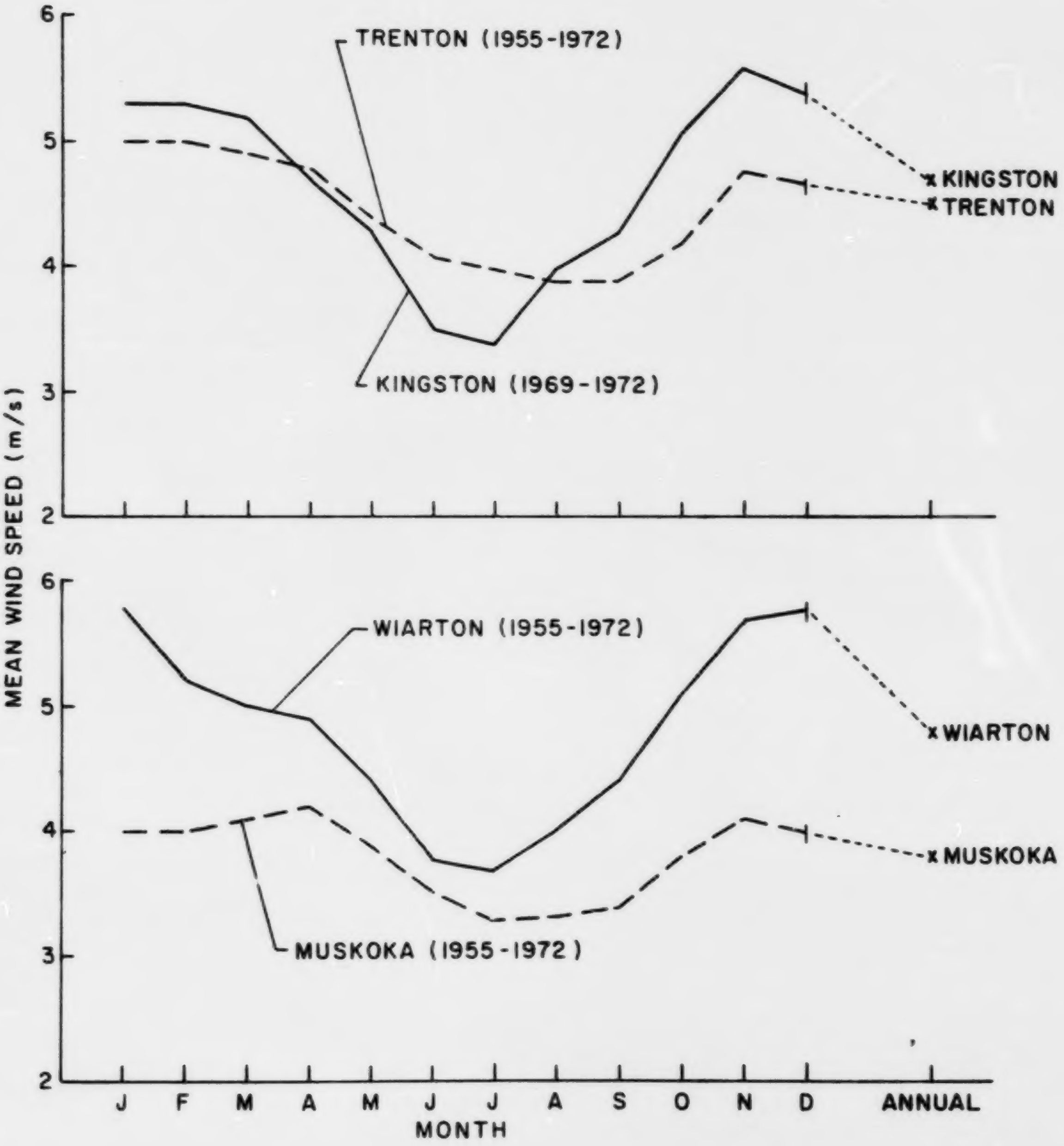
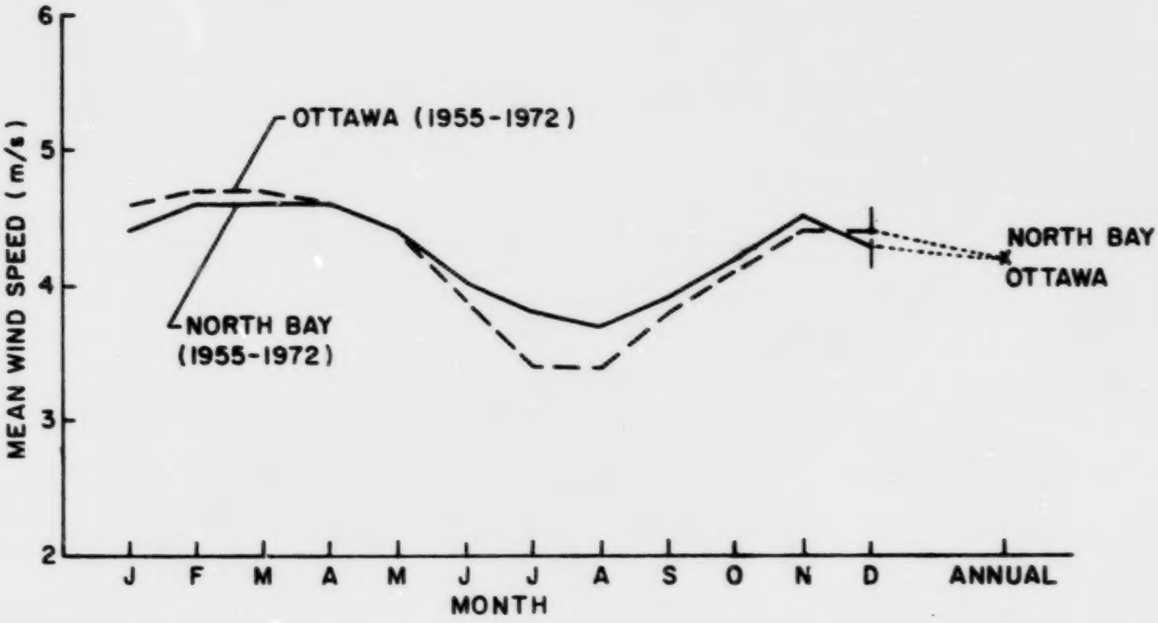


FIG. 5.4 MEAN WIND SPEEDS (ALL DIRECTIONS) FOR SOUTHERN ONTARIO STATIONS.



APPENDIX 6

WIND DURATION SUMMARIES
(% FREQUENCY)

TABLE 6.1

Wind Duration Summary (% Frequency)
Toronto (January 1971 - December 1980)

Wind Condition		Time Interval (hrs)					
		1-6	7-12	13-24	25-48	≥49	Total
N-NNE	0.5-2.9 m/s	9.0	0.2				9.2
	3-6.9 m/s	5.4	0.3	0.1			5.8
	≥ 7.0 m/s	1.3					1.3
NE-ENE	0.5-2.9 m/s	2.0					2.0
	3-6.9 m/s	2.0	0.1				2.1
	≥ 7.0 m/s	0.4					0.4
E-ESE	0.5-2.9 m/s	2.8					2.8
	3-6.9 m/s	3.4	0.2	0.1			3.7
	≥ 7.0 m/s	0.9	0.1				1.0
SE-SSE	0.5-2.9 m/s	4.4					4.4
	3-6.9 m/s	4.2	0.1				4.3
	≥ 7.0 m/s	0.3					0.3
S-SSW	0.5-2.9 m/s	5.7					5.7
	3-6.9 m/s	4.9	0.1				5.0
	≥ 7.0 m/s	0.8					0.8
SW-WSW	0.5-2.9 m/s	4.9					4.9
	3-6.9 m/s	6.1	0.2				6.3
	≥ 7.0 m/s	2.0	0.1				2.1
W-WNW	0.5-2.9 m/s	6.0					6.0
	3-6.9 m/s	7.2	0.2				7.4
	≥ 7.0 m/s	3.0	0.2				3.2
NW-NNW	0.5-2.9 m/s	6.0					6.0
	3-6.9 m/s	6.9	0.2				7.1
	≥ 7.0 m/s	2.4	0.1	0.1			2.6
Calm		5.5	0.1				5.6
All	0.5-2.9 m/s	40.8	0.2	0.0			41.0
Direc-	3-6.9 m/s	40.1	1.4	0.2			41.7
tions	≥ 7.0 m/s	11.1	0.5	0.1			11.7
Total		97.5	2.2	0.3	0.0	0.0	100.0

TABLE 6.2

Wind Duration Summary (% Frequency)
London (January 1971 - December 1980)

Wind Condition		Time Interval (hrs)					
		1-6	7-12	13-24	25-48	≥49	Total
N-NNE	0.5-2.9 m/s	7.8	0.3				8.1
	3-6.9 m/s	3.0	0.2				3.2
	≥ 7.0 m/s	0.4					0.4
NE-ENE	0.5-2.9 m/s	3.5					3.5
	3-6.9 m/s	2.6	0.1				2.7
	≥ 7.0 m/s	0.5	0.1				0.6
E-ESE	0.5-2.9 m/s	5.1	0.1				5.2
	3-6.9 m/s	4.1	0.4	0.1			4.6
	≥ 7.0 m/s	1.1	0.1				1.2
SE-SSE	0.5-2.9 m/s	4.2					4.2
	3-6.9 m/s	3.3	0.1				3.4
	≥ 7.0 m/s	0.4					0.4
S-SSW	0.5-2.9 m/s	4.8					4.8
	3-6.9 m/s	6.2	0.4	0.1			6.7
	≥ 7.0 m/s	1.8	0.1				1.9
SW-WSW	0.5-2.9 m/s	4.2					4.2
	3-6.9 m/s	6.8	0.4	0.1			7.3
	≥ 7.0 m/s	2.3	0.1				2.4
W-WNW	0.5-2.9 m/s	5.9	0.1				6.0
	3-6.9 m/s	7.8	0.5	0.1			8.4
	≥ 7.0 m/s	2.5	0.2				2.7
NW-NNW	0.5-2.9 m/s	4.9					4.9
	3-6.9 m/s	5.9	0.3				6.2
	≥ 7.0 m/s	1.5	0.1				1.6
Calm		5.2	0.2				5.4
All	0.5-2.9 m/s	40.4	0.5	0.0			40.9
Direc-	3-6.9 m/s	39.7	2.4	0.4			42.5
tions	≥ 7.0 m/s	10.5	0.7	0.0			11.2
Total		95.8	3.8	0.4	0.0	0.0	100.0

TABLE 6.3

Wind Duration Summary (% Frequency)
Sarnia (August 1973 to December 1980)

		Time Interval (hrs)					
Wind Condition		1-6	7-12	13-24	25-48	≥49	Total
N-NNE	0.5-2.9 m/s	7.5	0.4	0.1			8.0
	3-6.9 m/s	5.1	0.6	0.1			5.8
	≥ 7.0 m/s	1.5	0.2	0.1			1.8
NE-ENE	0.5-2.9 m/s	3.6					3.6
	3-6.9 m/s	3.1	0.1				3.2
	≥ 7.0 m/s	0.5					0.5
E-ESE	0.5-2.9 m/s	4.5	0.6				5.1
	3-6.9 m/s	2.2	0.2				2.4
	≥ 7.0 m/s	0.5					0.5
SE-SSE	0.5-2.9 m/s	4.7	0.1				4.8
	3-6.9 m/s	3.5	0.3				3.8
	≥ 7.0 m/s	0.7	0.1				0.8
S-SSW	0.5-2.9 m/s	7.8	0.4				8.2
	3-6.9 m/s	7.3	0.9	0.3			8.5
	≥ 7.0 m/s	1.8	0.2				2.0
SW-WSW	0.5-2.9 m/s	5.1					5.1
	3-6.9 m/s	6.5	0.3				6.8
	≥ 7.0 m/s	1.9	0.1				2.0
W-WNW	0.5-2.9 m/s	4.0					4.0
	3-6.9 m/s	6.3	0.5	0.1			6.9
	≥ 7.0 m/s	2.5	0.2	0.1			2.8
NW-NNW	0.5-2.9 m/s	2.5					2.5
	3-6.9 m/s	4.3	0.2				4.5
	≥ 7.0 m/s	1.8	0.2	0.1			2.1
Calm		4.0	0.3				4.3
All Directions	0.5-2.9 m/s	39.7	1.5	0.1			41.3
	3-6.9 m/s	38.3	3.1	0.5			41.9
	≥ 7.0 m/s	11.2	1.0	0.3			12.5
Total		93.2	5.9	0.9	0.0	0.0	100.0

TABLE 6.4

Wind Duration Summary (% Frequency)
Kingston (January 1971 to December 1980)

Wind Condition		Time Interval (hrs)					
		1-6	7-12	13-24	25-48	≥49	Total
N-NNE	0.5-2.9 m/s	4.5	0.2	0			4.7
	3-6.9 m/s	5.4	0.6	0.2			6.2
	≥ 7.0 m/s	1.6	0.2	0			1.8
NE-ENE	0.5-2.9 m/s	3.6	0.1	0			3.7
	3-6.9 m/s	3.7	0.7	0.3			4.7
	≥ 7.0 m/s	1.2	0.2	0.1			1.5
E-ESE	0.5-2.9 m/s	2.4	0	0			2.4
	3-6.9 m/s	2.4	0.2	0			2.6
	≥ 7.0 m/s	0.3	0	0			0.3
SE-SSE	0.5-2.9 m/s	2.8	0	0			2.8
	3-6.9 m/s	3.6	0.1	0			3.7
	≥ 7.0 m/s	1.2	0.1	0			1.3
S-SSW	0.5-2.9 m/s	5.1	0.1	0			5.2
	3-6.9 m/s	6.6	1.3	0.4			8.3
	≥ 7.0 m/s	3.1	0.4	0.2			3.7
SW-WSW	0.5-2.9 m/s	4.2	0	0			4.2
	3-6.9 m/s	7.3	0.6	0.1			8.0
	≥ 7.0 m/s	2.9	0.4	0.1			3.4
W-WNW	0.5-2.9 m/s	4.7	0.8	0			5.5
	3-6.9 m/s	6.3	0.9	0.2			7.4
	≥ 7.0 m/s	2.4	0.3	0			2.7
NW-NNW	0.5-2.9 m/s	3.7	0	0			3.7
	3-6.9 m/s	4.8	0.4	0.1			5.3
	≥ 7.0 m/s	1.4	0.1	0			1.5
Calm		5.0	0.3	0.1			5.4
All Directions	0.5-2.9 m/s	31.0	1.2	0			32.2
	3-6.9 m/s	40.1	4.8	1.3			46.2
	≥ 7.0 m/s	14.1	1.7	0.4			16.2
Total		90.2	8.0	1.8	0.0	0.0	100.0

TABLE 6.5

Wind Duration Summary (% Frequency)
Ottawa (January 1971 to December 1980)

Wind Condition		Time Interval (hrs)					
		1-6	7-12	13-24	25-48	≥49	Total
	0.5-2.9 m/s	3.6	0.1				3.7
N-NNE	3-6.9 m/s	3.1	0.3	0.1			3.5
	≥ 7.0 m/s	0.6					0.6
	0.5-2.9 m/s	4.5	0.2				4.7
NE-ENE	3-6.9 m/s	3.7	0.5	0.1			4.3
	≥ 7.0 m/s	0.7	0.1	0.1			0.9
	0.5-2.9 m/s	4.6	0.2				4.8
E-ESE	3-6.9 m/s	3.6	0.5	0.2			4.3
	≥ 7.0 m/s	0.9	0.1				1.0
	0.5-2.9 m/s	3.7	0.1				3.8
SE-SSE	3-6.9 m/s	1.7	0.1				1.8
	≥ 7.0 m/s	0.1					0.1
	0.5-2.9 m/s	7.1	0.6	0.1			7.8
S-SSW	3-6.9 m/s	4.7	0.7	0.2			5.6
	≥ 7.0 m/s	0.8					0.8
	0.5-2.9 m/s	7.4	0.3				7.7
SW-WSW	3-6.9 m/s	5.4	0.5	0.1			6.0
	≥ 7.0 m/s	1.1	0.1				1.2
	0.5-2.9 m/s	6.8	0.3				7.1
W-WNW	3-6.9 m/s	6.2	1.2	0.3			7.7
	≥ 7.0 m/s	2.0	0.3	0.1			2.4
	0.5-2.9 m/s	4.0	0.1				4.1
NW-NNW	3-6.9 m/s	5.1	0.5	0.1			5.7
	≥ 7.0 m/s	1.6	0.1				1.7
Calm		7.6	0.8	0.3			8.7
All Directions	0.5-2.9 m/s	41.7	1.9	0.1			43.7
	3-6.9 m/s	33.5	4.3	1.1			38.9
	≥ 7.0 m/s	7.8	0.7	0.2			8.7
Total		90.6	7.7	1.7	0.0	0.0	100.0

TABLE 6.6

Wind Duration Summary (% Frequency)
North Bay (January 1971 to December 1980)

Wind Condition		Time Interval (hrs)					
		1-6	7-12	13-24	25-48	≥49	Total
N-NNE	0.5-2.9 m/s	5.4	0.3	0.1			5.8
	3-6.9 m/s	4.9	0.9	0.4			6.2
	≥ 7.0 m/s	1.4	0.2	0.1			1.7
NE-ENE	0.5-2.9 m/s	3.5	0.1				3.6
	3-6.9 m/s	3.3	0.4	0.1			3.8
	≥ 7.0 m/s	0.6	0.1				0.7
E-ESE	0.5-2.9 m/s	4.2	0.2				4.4
	3-6.9 m/s	3.1	0.6	0.3			4.0
	≥ 7.0 m/s	0.8	0.1	0.1			1.0
SE-SSE	0.5-2.9 m/s	4.4	0.2				4.6
	3-6.9 m/s	3.3	0.3				3.6
	≥ 7.0 m/s	0.2	0.0				0.2
S-SSW	0.5-2.9 m/s	7.1	0.2				7.3
	3-6.9 m/s	5.7	0.7	0.2			6.6
	≥ 7.0 m/s	0.9	0.1				1.0
SW-WSW	0.5-2.9 m/s	7.2	0.4				7.6
	3-6.9 m/s	6.8	1.2	0.4			8.4
	≥ 7.0 m/s	1.6	0.2				1.8
W-WNW	0.5-2.9 m/s	6.1	0.3				6.4
	3-6.9 m/s	4.7	0.4	0.1			5.2
	≥ 7.0 m/s	0.6	0.0				0.6
NW-NNW	0.5-2.9 m/s	4.9	0.2				5.1
	3-6.9 m/s	3.6	0.4	0.1			4.1
	≥ 7.0 m/s	0.8	0.0				0.8
Calm		5.0	0.4	0.1			5.5
All Directions	0.5-2.9 m/s	42.8	1.9	0.1			44.8
	3-6.9 m/s	35.4	4.9	1.6			41.9
	≥ 7.0 m/s	6.9	0.7	0.2			7.8
Total		90.1	7.9	2.0	0.0	0.0	100.00

APPENDIX 7

ANNUAL, SUMMER AND WINTER

MIXED LAYER STATISTICS FOR MANIWAKI, QUEBEC; FLINT, MICHIGAN; SAULT STE. MARIE, MICHIGAN; BUFFALO, NEW YORK.

(1966 - 1969)

% FREQUENCY OF OCCURRENCE (x 10)

Wind Speed in the Mixed Layer (metres/second)	Maximum Mixing Height (metres)												Total
	0	1 to 199	200 to 399	400 to 599	600 to 799	800 to 999	1000 to 1199	1200 to 1399	1400 to 1599	1600 to 1799	1800 to 1999	2000 +	
0.0 - 2.0	1	17	37	17	14	12	7	7	5	1	3	4	125
2.1 - 4.0	4	13	27	41	31	22	14	14	17	9	11	12	215
4.1 - 6.0		12	16	38	35	33	21	22	17	18	14	22	248
6.1 - 8.0	1	1	9	29	25	25	20	17	17	13	13	22	192
8.1 - 10.0		1	4	15	14	21	12	15	14	7	5	17	125
10.1 - 12.0				2	4	8	7	11	10	5	6	7	60
12.1 - 14.0					1	4	2	3	2	4	1	3	20
14.1 - 16.0			1		1	3	3	1	1		2		12
16.1 - 18.0													
18.1 - 20.0					1						1	1	3
20.1 - 30.0													
30.1 +													
Total	6	44	94	142	126	128	86	90	83	57	56	88	1,000

TABLE 7.1

Maximum mixing height vs. wind speed in the mixed layer

Maniwaki - Annual

% FREQUENCY OF OCCURRENCE (x 10)

Wind Speed in the Mixed Layer (metres/second)	Maximum Mixing Height (metres)											Total
	0	1 to 199	200 to 399	400 to 599	600 to 799	800 to 999	1000 to 1199	1200 to 1399	1400 to 1599	1600 to 1799	1800 to 1999	2000 +	
0.0 - 2.0		6	10	4	6	13	10	8	7	2	6	7	79
2.1 - 4.0	6	6	13	14	27	10	8	25	31	15	17	23	195
4.1 - 6.0		7	11	18	25	29	31	35	28	33	28	39	284
6.1 - 8.0		2	4	15	15	19	18	19	28	23	21	42	206
8.1 - 10.0		2	2	7	6	12	14	21	19	11	10	27	131
10.1 - 12.0					2	7	8	11	14	10	8	11	71
12.1 - 14.0						2	2	2	2	7	2	4	21
14.1 - 16.0						2	3				4		9
16.1 - 18.0													
18.1 - 20.0											2	2	4
20.1 - 30.0													
30.1 +													
Total	6	23	40	58	81	94	94	121	129	101	98	155	1,000

TABLE 7.2

Maximum mixing height vs. wind speed in the mixed layer

Maniwaki - Summer

% FREQUENCY OF OCCURRENCE (x 10)

Wind Speed in the Mixed Layer (metres/second)	Maximum Mixing Height (metres)												Total
	0	1 to 199	200 to 399	400 to 599	600 to 799	800 to 999	1000 to 1199	1200 to 1399	1400 to 1599	1600 to 1799	1800 to 1999	2000 +	
0.0 - 2.0	3	30	66	32	22	13	7	6	2				181
2.1 - 4.0	3	20	42	71	36	36	21	2	3	2	4		240
4.1 - 6.0		18	21	60	46	36	11	9	6	2		2	211
6.1 - 8.0	2		13	44	36	31	21	13	4	3	5		172
8.1 - 10.0		2	4	24	22	30	9	9	9	3		6	118
10.1 - 12.0				4	7	9	4	7	6		3	2	42
12.1 - 14.0					2	6	3	4	2			2	19
14.1 - 16.0			2		2	3	3	3	2				15
16.1 - 18.0													
18.1 - 20.0					2								2
20.1 - 30.0													
30.1 +													
Total	8	70	148	235	175	164	79	53	34	10	12	12	1,000

TABLE 7.3

Maximum mixing heights vs. wind speed in the mixed layer

Maniwaki - Winter

% FREQUENCY OF OCCURRENCE (x 10)

Wind Speed in the Mixed Layer (metres/second)	Maximum Mixing Height (metres)												Total
	0	1 to 199	200 to 399	400 to 599	600 to 799	800 to 999	1000 to 1199	1200 to 1399	1400 to 1599	1600 to 1799	1800 to 1999	2000 +	
0.0 - 2.0	2	2	7	7	2	3	1	1	1	1	1		28
2.1 - 4.0	9	14	23	17	18	18	12	16	15	16	10	8	176
4.1 - 6.0	2	16	25	23	28	34	16	21	17	17	12	18	229
6.1 - 8.0	4	7	23	23	25	24	16	15	19	9	10	16	191
8.1 - 10.0	4	4	12	21	19	14	12	17	15	9	10	10	147
10.1 - 12.0	1	3	6	12	13	12	17	12	8	7	6	8	105
12.1 - 14.0		1	6	5	7	9	9	6	6	2	4	3	58
14.1 - 16.0	1		2	1	4	4	3	4	2	6	1	6	34
16.1 - 18.0	1		1		2	3	2	2	2	1	1		15
18.1 - 20.0					1	1	2	1	2	2		1	10
20.1 - 30.0						1		2			2	2	7
30.1 +													
Total	24	47	105	109	119	123	90	97	87	70	57	72	1,000

TABLE 7.4

Maximum mixing height vs. wind speed in the mixed layer

Buffalo - Annual

% FREQUENCY OF OCCURRENCE (x 10)

Wind Speed in the Mixed Layer (metres/second)	Maximum Mixing Height (metres)												
	0	1 to 199	200 to 399	400 to 599	600 to 799	800 to 999	1000 to 1199	1200 to 1399	1400 to 1599	1600 to 1799	1800 to 1999	2000 +	Total
0.0 - 2.0		1	8		2	2		2	2	3	2	15	37
2.1 - 4.0		4	8	6	8	14	15	28	25	30	19	35	192
4.1 - 6.0	2	10	19	4	23	34	15	32	32	30	30	30	261
6.1 - 8.0		2	13	13	18	23	17	19	31	17	18	17	188
8.1 - 10.0	2	6	7	8	11	15	6	23	23	15	12	14	142
10.1 - 12.0		2	3	2	10	11	12	19	10	10	4	4	87
12.1 - 14.0			2	2	4	3	8	4	8	2	4	10	47
14.1 - 16.0				2	3	2		4	3	6	2		22
16.1 - 18.0					2	3	3	3	2	2	2		17
18.1 - 20.0									3			2	5
20.1 - 30.0								2					– 2
30.1 +													
Total	4	25	60	37	81	107	76	136	139	115	93	127	1,000

TABLE 7.5

Maximum mixing height vs. wind speed in the mixed layer

Buffalo - Summer

% FREQUENCY OF OCCURRENCE (x 10)

Wind Speed in the Mixed Layer (metres/second)	Maximum Mixing Height (metres)												Total
	0	1 to 199	200 to 399	400 to 599	600 to 799	800 to 999	1000 to 1199	1200 to 1399	1400 to 1599	1600 to 1799	1800 to 1999	2000 +	
0.0 - 2.0	3	3	6	15	3	6	3						39
2.1 - 4.0	18	24	39	29	29	23	7	3	3	2			177
4.1 - 6.0	2	20	30	42	34	35	16	9	2	3			193
6.1 - 8.0	7	12	33	35	34	27	15	11	6		2	2	184
8.1 - 10.0	6	3	18	35	30	14	18	12	4	2	6	3	151
10.1 - 12.0	2	4	9	25	13	14	23	6	6	4	4	2	112
12.1 - 14.0		2	11	9	12	15	7	7	3	2	2	2	72
14.1 - 16.0	2		3		4	7	6	3	2	4		2	33
16.1 - 18.0	2		2		2	3	2	2	3				16
18.1 - 20.0					2	2	3	2		3		2	14
20.1 - 30.0						2		2			3	2	9
30.1 +													
Total	42	68	151	190	163	148	100	57	29	20	17	15	1,000

TABLE 7.6

Maximum mixing height vs. wind speed in the mixed layer

Buffalo - Winter

% FREQUENCY OF OCCURRENCE (x 10)

Wind Speed in the Mixed Layer (metres/second)	Maximum Mixing Height (metres)												Total
	0	1 to 199	200 to 399	400 to 599	600 to 799	800 to 999	1000 to 1199	1200 to 1399	1400 to 1599	1600 to 1799	1800 to 1999	2000 +	
0.0 - 2.0	1	1	5	1	4	5	3	6	5	5	4	1	41
2.1 - 4.0	1	5	17	22	24	18	16	13	17	14	9	11	167
4.1 - 6.0	4	11	28	29	29	31	27	29	21	18	14	12	253
6.1 - 8.0	3	5	21	26	24	26	16	14	19	14	12	14	194
8.1 - 10.0	1	3	14	20	19	18	25	18	14	9	11	12	164
10.1 - 12.0		1	8	5	13	18	18	10	6	6	4	4	93
12.1 - 14.0		1	6	3	4	6	8	5	5	3	2	4	47
14.1 - 16.0			1	1	3	6	3	5	2	5		2	28
16.1 - 18.0					1	4		1	1		1		8
18.1 - 20.0							1	1	1			1	4
20.1 - 30.0										1			1
30.1 +													
Total	10	27	100	107	121	132	117	102	91	75	57	62	1,000

TABLE 7.7

Maximum mixing height vs. wind speed in the mixed layer

Flint - Annual

% FREQUENCY OF OCCURRENCE (x 10)

Wind Speed in the Mixed Layer (metres/second)	Maximum Mixing Height (metres)												Total
	0	1 to 199	200 to 399	400 to 599	600 to 799	800 to 999	1000 to 1199	1200 to 1399	1400 to 1599	1600 to 1799	1800 to 1999	2000 +	
0.0 - 2.0			2		2	6		6	8	8	7	2	41
2.1 - 4.0	2		8	15	25	13	18	14	27	25	17	21	185
4.1 - 6.0	2	4	17	17	18	29	27	38	36	31	27	23	269
6.1 - 8.0		4	13	10	18	21	19	14	31	18	23	25	196
8.1 - 10.0		3	2	11	19	10	23	18	23	15	18	19	161
10.1 - 12.0		2	4	3	8	15	13	10	8	7	6	7	83
12.1 - 14.0		2	2	2	2	4	6	7	2	2	2	6	37
14.1 - 16.0			2			2	4	4	2	2		2	18
16.1 - 18.0						2		2			2		6
18.1 - 20.0												2	2
20.1 - 30.0										2			2
30.1 +													
Total	4	15	50	58	92	102	110	113	137	110	102	107	1,000

TABLE 7.8

Maximum mixing height vs. wind speed in the mixed layer

Flint - Summer

% FREQUENCY OF OCCURRENCE (x 10)

Wind Speed in the Mixed Layer (metres/second)	Maximum Mixing Height (metres)												Total
	0	1 to 199	200 to 399	400 to 599	600 to 799	800 to 999	1000 to 1199	1200 to 1399	1400 to 1599	1600 to 1799	1800 to 1999	2000 +	
0.0 - 2.0	3	3	7	3	6	4	6	6	2	2			42
2.1 - 4.0		10	27	29	22	24	13	12	6	3	2	2	150
4.1 - 6.0	4	19	40	43	41	34	28	21	6	4			240
6.1 - 8.0	6	6	29	40	29	31	13	15	6	9	2	2	188
8.1 - 10.0	1	3	25	29	18	27	27	18	3	2	3	4	160
10.1 - 12.0			12	7	18	21	24	10	7	6	3		108
12.1 - 14.0			12	4	6	9	10	3	6	3	3	2	58
14.1 - 16.0			1	1	6	10	2	6	4	7		2	39
16.1 - 18.0					3	4			3				10
18.1 - 20.0							1	3				1	5
20.1 - 30.0													
30.1 +													
Total	14	41	153	156	149	164	124	94	43	36	13	13	1,000

TABLE 7.9

Maximum mixing height vs. wind speed in the mixed layer

Flint - Winter

% FREQUENCY OF OCCURRENCE (x 10)

Wind Speed in the Mixed Layer (metres/second)	Maximum Mixing Height (metres)												
	0	1 to 199	200 to 399	400 to 599	600 to 799	800 to 999	1000 to 1199	1200 to 1399	1400 to 1599	1600 to 1799	1800 to 1999	2000 +	Total
0.0 - 2.0	1	7	10	11	1	2	3	1				1	37
2.1 - 4.0	1	25	33	30	22	14	12	10	6	3	6	6	168
4.1 - 6.0	3	21	39	44	30	25	14	14	17	10	9	10	236
6.1 - 8.0	1	11	29	41	39	28	23	15	11	12	9	12	231
8.1 - 10.0	1	9	20	28	22	19	9	15	9	6	4	12	154
10.1 - 12.0	1	1	10	20	13	17	7	9	5	4	2	5	94
12.1 - 14.0			2	9	6	7	7	4	2	3	1	7	48
14.1 - 16.0			2	1	2	4	4	1				1	15
16.1 - 18.0			1	1		1	2	2	1	1	1		10
18.1 - 20.0		1	1			1							3
20.1 - 30.0						1	1				1	1	4
30.1 +													
Total	8	75	147	185	135	119	82	71	51	39	33	55	1,000

TABLE 7.10

Maximum mixing height vs. wind speed in the mixed layer

Sault Ste. Marie - Annual

% FREQUENCY OF OCCURRENCE (x 10)

Wind Speed in the Mixed Layer (metres/second)	Maximum Mixing Height (metres)												Total
	0	1 to 199	200 to 399	400 to 599	600 to 799	800 to 999	1000 to 1199	1200 to 1399	1400 to 1599	1600 to 1799	1800 to 1999	2000 +	
0.0 - 2.0		2	4	4		2	4	2				2	20
2.1 - 4.0		7	19	14	18	11	15	17	13	6	11	11	142
4.1 - 6.0	2	17	25	21	27	31	18	19	29	15	17	19	240
6.1 - 8.0		7	19	34	32	31	34	23	19	23	18	23	263
8.1 - 10.0		8	13	19	18	21	8	23	15	8	8	23	164
10.1 - 12.0			6	18	10	14	7	14	10	6	4	8	97
12.1 - 14.0				6	2	7	4	4	4	2	2	11	42
14.1 - 16.0			2		2	4	2	2				2	14
16.1 - 18.0			2				4	2		2	2		12
18.1 - 20.0													
20.1 - 30.0						2	2				2		6
30.1 +													
Total	2	41	90	116	109	123	98	106	90	62	64	99	1,000

TABLE 7.11

Maximum mixing height vs. wind speed in the mixed layer

Sault Ste. Marie - Summer

% FREQUENCY OF OCCURRENCE (x 10)

Wind Speed in the Mixed Layer (metres/second)	Maximum Mixing Height (metres)												Total
	0	1 to 199	200 to 399	400 to 599	600 to 799	800 to 999	1000 to 1199	1200 to 1399	1400 to 1599	1600 to 1799	1800 to 1999	2000 +	
0.0 - 2.0	2	14	16	18	2	3	2						57
2.1 - 4.0	4	44	50	47	27	16	9	3					200
4.1 - 6.0	4	25	54	70	34	20	9	7	2	4	2		231
6.1 - 8.0	2	15	41	48	47	25	12	6	2				198
8.1 - 10.0	3	11	29	36	27	16	9	6	2	2		2	143
10.1 - 12.0	2	2	15	21	16	20	7	3		2		2	90
12.1 - 14.0			4	11	9	6	9	3		2		2	46
14.1 - 16.0			3	2	2	4	6	2					19
16.1 - 18.0				2		2		2	2				8
18.1 - 20.0		2	2			2							6
20.1 - 30.0												2	2
30.1 +													
Total	17	113	214	255	164	114	63	32	8	10	2	8	1,000

TABLE 7.12

Maximum mixing height vs. wind speed in the mixed layer

Sault Ste. Marie - Winter

% FREQUENCY OF OCCURRENCE (x 10)

Wind Direction in the Mixed Layer (degrees)	Maximum Mixing Height (metres)											
	0	1 to 199	200 to 399	400 to 599	600 to 799	800 to 999	1000 to 1199	1200 to 1399	1400 to 1599	1600 to 1799	1800 to 1999	2000 +	Total
CALM		4	4	4	4	1	1	2	2	1	2	2	27
10 - 40		2	6	11	5	13	4	4	2	4	2	2	55
50 - 80			2	6	3	7	1		1	2	3	2	27
90 - 120			7	7	2	2	2	2	3	2	1	2	30
130 - 160		3	10	13	12	12	7	4	5	1	4	2	73
170 - 200		6	17	34	23	18	18	8	8	3	6	5	146
210 - 240		4	8	19	17	21	17	18	20	10	12	15	161
250 - 280	2	5	12	17	18	13	10	18	12	11	8	31	157
290 - 320	1	12	11	19	26	18	17	20	19	7	12	20	182
330 - 360	4	11	16	15	18	20	9	12	11	12	8	6	142
Total	7	47	93	145	128	125	86	88	83	53	58	87	1,000

TABLE 7.13

Maximum mixing height vs. wind direction in the mixed layer

Maniwaki - Annual

% FREQUENCY OF OCCURRENCE (x 10)

Wind Direction in the Mixed Layer (degrees)	Maximum Mixing Height (metres)												
	0	1 to 199	200 to 399	400 to 599	600 to 799	800 to 999	1000 to 1199	1200 to 1399	1400 to 1599	1600 to 1799	1800 to 1999	2000 +	Total
CALM					3		2	3	3	2	2	3	18
10 - 40		2	4	3	2	7	3	7	5	7	3	5	48
50 - 80			2	3	2	5			2	3	6	5	28
90 - 120			4	4		2		5	6	3	2	3	29
130 - 160			4	7	7	5	9	7	6		7	5	57
170 - 200			10	10	15	5	23	10	13	6	10	10	112
210 - 240				7	13	17	22	24	28	19	20	27	177
250 - 280	2	3	6	9	15	9	6	24	20	30	13	54	191
290 - 320		9	4	13	13	10	16	27	28	13	23	36	192
330 - 360	4	11	6	5	15	17	10	16	16	21	16	11	148
Total	6	25	40	61	85	77	91	123	127	104	102	159	1,000

TABLE 7.14

Maximum mixing height vs. wind direction in the mixed layer

Maniwaki - Summer

% FREQUENCY OF OCCURRENCE (x 10)

Wind Direction in the Mixed Layer (degrees)	Maximum Mixing Height (metres)												
	0	1 to 199	200 to 399	400 to 599	600 to 799	800 to 999	1000 to 1199	1200 to 1399	1400 to 1599	1600 to 1799	1800 to 1999	2000 +	Total
CALM		8	9	8	5	3					1		34
10 - 40		2	8	11	9	20	5	2					57
50 - 80			3	9	4	9	2						27
90 - 120			14	9	3	2	3						31
130 - 160		6	15	20	18	12	5		2	2	1		81
170 - 200		12	24	59	32	24	14	6	3		2		176
210 - 240		8	17	32	21	26	12	12	11	2	5	2	148
250 - 280	1	8	18	26	21	18	14	11	3	5	3	8	136
290 - 320	1	14	18	26	41	27	18	14	9			3	171
330 - 360	5	11	26	26	23	24	8	8	6	2			139
Total	7	69	152	226	177	165	81	53	34	11	12	13	1,000

TABLE 7.15

Maximum mixing height vs. wind direction in the mixed layer

Maniwaki - Winter

% FREQUENCY OF OCCURRENCE (x 10)

Wind Direction in the Mixed Layer (degrees)	Maximum Mixing Height (metres)												
	0	1 to 199	200 to 399	400 to 599	600 to 799	800 to 999	1000 to 1199	1200 to 1399	1400 to 1599	1600 to 1799	1800 to 1999	2000 +	Total
CALM			1	1	1				1		1		5
10 - 40	4	2	7	6	7	5	3	1	3	6	5	1	50
50 - 80		6	7	8	7	10	5	2	1	2	1	2	51
90 - 120		2	2	6	7	6	5	3	5	3	1	1	41
130 - 160			4	5	5	7	6	4	5	3	1	5	45
170 - 200	1	5	13	12	5	8	5	7	7	7	5	7	82
210 - 240	5	14	25	22	28	30	21	26	18	15	17	17	238
250 - 280	6	8	28	30	42	40	28	28	27	16	11	20	284
290 - 320	3	5	10	17	11	13	10	19	15	14	10	9	136
330 - 360	5	5	10	5	9	7	3	7	4	1	5	7	68
Total	24	47	107	112	122	126	86	97	86	67	57	69	1,000

TABLE 7.16

Maximum mixing height vs. wind direction in the mixed layer

Buffalo - Annual

% FREQUENCY OF OCCURRENCE (x 10)

Wind Direction in the Mixed Layer (degrees)	Maximum Mixing Height (metres)												
	0	1 to 199	200 to 399	400 to 599	600 to 799	800 to 999	1000 to 1199	1200 to 1399	1400 to 1599	1600 to 1799	1800 to 1999	2000 +	Total
CALM			2						2		2		6
10 - 40	2	2	4	2	6	6	4	2	6	11	9	2	56
50 - 80		2	2	6	4	11	6	4	2	4	2	4	47
90 - 120		2		2	2	2	6	6	9	6	2	2	39
130 - 160			2	2		4	2	3	9	10		9	41
170 - 200		2	7		2	2	2	15	11	11	7	11	70
210 - 240	2	7	22	7	16	23	17	41	25	26	31	29	246
250 - 280		6	9	10	35	42	22	28	42	25	11	33	263
290 - 320		3	6	4	7	9	9	26	26	22	18	18	148
330 - 360	2	3	9	2	11	9	4	11	7	2	11	13	84
Total	6	27	63	35	83	108	72	136	139	117	93	121	1,000

TABLE 7.17

Maximum mixing height vs. wind direction in the mixed layer

Buffalo - Summer

% FREQUENCY OF OCCURRENCE (x 10)

Wind Direction in the Mixed Layer (degrees)	Maximum Mixing Height (metres)												
	0	1 to 199	200 to 399	400 to 599	600 to 799	800 to 999	1000 to 1199	1200 to 1399	1400 to 1599	1600 to 1799	1800 to 1999	2000 +	Total
CALM				2	2				2				6
10 - 40	7	3	9	9	7	3	2	2					42
50 - 80		11	12	11	9	7	5						55
90 - 120		3	5	9	14	11	5						47
130 - 160			7	7	9	11	9	5			2		50
170 - 200	2	9	18	25	9	16	7		3	3	2	2	96
210 - 240	7	20	28	37	40	37	25	9	11	3	2	5	224
250 - 280	12	12	49	51	49	37	34	28	11	6	11	6	306
290 - 320	7	7	12	31	16	19	11	11	3	6	2		125
330 - 360	7	7	12	7	7	5	2	2					49
Total	42	72	152	189	162	146	100	57	30	18	19	13	1,000

TABLE 7.18

Maximum mixing height vs. wind direction in the mixed layer

Buffalo - Winter

% FREQUENCY OF OCCURRENCE (x 10)

Wind Direction in the Mixed Layer (degrees)	Maximum Mixing Height (metres)												
	0	1 to 199	200 to 399	400 to 599	600 to 799	800 to 999	1000 to 1199	1200 to 1399	1400 to 1599	1600 to 1799	1800 to 1999	2000 +	Total
CALM			1	1	1	3		1	1		1		9
10 - 40	2	4	9	7	12	6	11	4	4	4	2	4	69
50 - 80	1	4	4	7	6	14	6	2	4	3	2	2	55
90 - 120	1	2	6	7	6	6	3	4	5	1	2	1	44
130 - 160		1	9	9	13	11	6	9	4	2	2	2	68
170 - 200		5	15	12	12	14	15	9	14	7	3	4	110
210 - 240	1	3	18	20	16	27	20	19	17	13	12	13	179
250 - 280	3	4	17	21	25	32	21	27	20	22	17	24	233
290 - 320	1	1	13	13	17	13	27	20	15	20	9	9	158
330 - 360	1	3	9	13	9	7	7	9	7	3	6	1	75
Total	10	27	101	110	117	133	116	104	91	75	56	60	1,000

TABLE 7.19

Maximum mixing height vs. wind direction in the mixed layer

Flint - Annual

% FREQUENCY OF OCCURRENCE (x 10)

Wind Direction in the Mixed Layer (degrees)	Maximum Mixing Height (metres)												Total
	0	1 to 199	200 to 399	400 to 599	600 to 799	800 to 999	1000 to 1199	1200 to 1399	1400 to 1599	1600 to 1799	1800 to 1999	2000 +	
CALM			2	2	3	6			3		3		19
10 - 40	2	2	10	7	10	6	11	4	8	8	4	8	80
50 - 80		3	3	3	4	12	8	4	8	6	4	4	59
90 - 120		2	3	4	4	4	3	7	8		4	3	42
130 - 160		2	10	3	11	7	7	15	8	4	4	4	75
170 - 200		2	6	8	6	10	17	10	19	13	4	7	102
210 - 240	2		3	6	11	25	19	27	23	21	21	19	177
250 - 280	2	3	7	10	19	23	23	23	25	25	28	43	231
290 - 320			2	6	14	4	18	14	23	28	14	15	138
330 - 360	2	2	7	10	10	4	4	8	10	6	11	3	77
Total	8	16	53	59	92	101	110	112	135	111	97	106	1,000

TABLE 7.20

Maximum mixing height vs. wind direction in the mixed layer

Flint - Summer

% FREQUENCY OF OCCURRENCE (x 10)

Wind Direction in the Mixed Layer (degrees)	Maximum Mixing Height (metres)												
	0	1 to 199	200 to 399	400 to 599	600 to 799	800 to 999	1000 to 1199	1200 to 1399	1400 to 1599	1600 to 1799	1800 to 1999	2000 +	Total
CALM								1					1
10 - 40	3	6	9	7	14	6	10	4					59
50 - 80	1	4	6	11	7	15	3						47
90 - 120	3	3	9	9	7	7	3		1	1			43
130 - 160		1	9	17	15	15	6	1					64
170 - 200		9	26	17	20	19	13	7	7	1	1		120
210 - 240		6	35	35	21	29	21	11	11	4	3	6	182
250 - 280	4	6	27	33	30	41	20	30	14	18	4	3	230
290 - 320	3	1	26	21	21	23	38	27	6	11	3	3	183
330 - 360		4	11	17	9	9	9	9	3				71
Total	14	40	158	167	144	164	123	90	42	35	11	12	1,000

TABLE 7.21

Maximum mixing height vs. wind direction in the mixed layer

Flint - Winter

% FREQUENCY OF OCCURRENCE (x 10)

Wind Direction in the Mixed Layer (degrees)	Maximum Mixing Height (metres)												Total
	0	1 to 199	200 to 399	400 to 599	600 to 799	800 to 999	1000 to 1199	1200 to 1399	1400 to 1599	1600 to 1799	1800 to 1999	2000 +	
CALM				4					1	1		1	7
10 - 40		2	7	15	6	9	2	7	2	3	1	3	57
50 - 80		5	11	8	4		1	2		1	2	1	35
90 - 120	2	20	33	14	8	4	2	2	2	1		2	90
130 - 160	1	6	16	30	14	19	9	5	2	1	1	2	106
170 - 200		1	6	17	11	7	7	12	6	1	2	4	74
210 - 240		4	7	20	14	15	11	15	9	9	15	16	135
250 - 280	1	4	13	9	14	13	9	8	17	7	5	17	117
290 - 320	3	24	42	47	49	35	31	16	11	10	5	7	280
330 - 360	2	9	14	20	15	14	9	4	4	2	5	1	99
Total	9	75	149	184	135	116	81	71	54	36	36	54	1,000

TABLE 7.22

Maximum mixing height vs. wind direction in the mixed layer

Sault Ste. Marie - Annual

% FREQUENCY OF OCCURRENCE (x 10)

Wind Direction in the Mixed Layer (degrees)	Maximum Mixing Height (metres)												Total
	0 -	1 to 199	200 to 399	400 to 599	600 to 799	800 to 999	1000 to 1199	1200 to 1399	1400 to 1599	1600 to 1799	1800 to 1999	2000 +	
CALM				2					2	2		2	8
10 - 40		2	2	2	4	8	2	13	4	6	2	6	51
50 - 80		2	7	4	2		2	3		3	3	2	28
90 - 120		6	14	10	11	2	2	4	2	2		4	57
130 - 160		2	8	21	15	23	13	10	2	3	2	4	103
170 - 200			4	6	11	7	7	17	11	3	3	7	76
210 - 240		2	6	8	8	15	6	20	13	15	27	30	150
250 - 280		2	6	6	7	14	13	11	31	11	10	30	141
290 - 320		15	40	49	45	38	40	25	19	14	10	13	308
330 - 360	2	2	8	8	4	13	11	6	7	4	10	3	78
Total	2	33	95	116	107	120	96	109	91	63	67	101	1,000

TABLE 7.23

Maximum mixing height vs. wind direction in the mixed layer

Sault Ste. Marie - Summer

% FREQUENCY OF OCCURRENCE (x 10)

Wind Direction in the Mixed Layer (degrees)	Maximum Mixing Height (metres)												Total
	0	1 to 199	200 to 399	400 to 599	600 to 799	800 to 999	1000 to 1199	1200 to 1399	1400 to 1599	1600 to 1799	1800 to 1999	2000 +	
CALM				6									6
10 - 40		2	12	27	7	11		2					61
50 - 80		9	15	12	7								43
90 - 120	4	34	55	18	5	5							121
130 - 160	2	11	25	40	12	16	5						111
170 - 200		2	7	29	11	7	6	6		3	2	2	75
210 - 240		7	7	34	20	16	17	9	5	3		3	121
250 - 280	2	7	21	12	21	12	6	5	2	6		2	96
290 - 320	6	29	51	44	53	32	21	6	3				245
330 - 360	2	12	23	32	26	16	7	3					121
Total	16	113	216	254	162	115	62	31	10	12	2	7	1,000

TABLE 7.24

Maximum mixing height vs. wind direction in the mixed layer

Sault Ste. Marie - Winter

% FREQUENCY OF OCCURRENCE (x 10)

Wind Speed in the Mixed Layer (metres/second)	Ventilation Coefficient (m^2/sec)/100												
	0 to 10	11 to 20	21 to 30	31 to 40	41 to 50	51 to 60	61 to 70	71 to 80	81 to 90	91 to 100	101 to 110	111 +	Total
0.0 - 2.0	88	22	12	2	1								125
2.1 - 4.0	30	57	48	28	20	12	11	4	4	1		1	216
4.1 - 6.0	11	17	36	36	27	26	24	17	19	13	6	18	250
6.1 - 8.0	1	3	10	19	19	17	19	16	12	12	16	47	191
8.1 - 10.0	1		2	4	9	6	10	12	11	5	9	54	123
10.1 - 12.0						1	2	3	2	1	6	45	60
12.1 - 14.0											3	17	20
14.1 - 16.0						1				1	1	11	14
16.1 - 18.0													
18.1 - 20.0												1	1
20.1 - 30.0													
30.1 +													
Total	131	99	108	89	76	63	66	52	48	33	41	194	1,000

TABLE 7.25

Ventilation coefficient vs. wind speed in the mixed layer

Maniwaki - Annual

REQUENCY OF OCCURRENCE (x 10)

Wind Speed in the Mixed Layer (metres/second)	Ventilation Coefficient $(m^2/sec)/100$												
	0 to 10	11 to 20	21 to 30	31 to 40	41 to 50	51 to 60	61 to 70	71 to 80	81 to 90	91 to 100	101 to 110	111 +	Total
0.0 - 2.0	29	20	15	4	3								71
2.1 - 4.0	17	19	34	28	33	23	19	7	8	2		2	192
4.1 - 6.0	7	10	21	24	27	32	34	31	31	24	11	33	285
6.1 - 8.0		3	7	9	7	15	13	15	11	20	23	85	208
8.1 - 10.0	2		3	3	3	2	5	7	10	4	11	84	134
10.1 - 12.0								2	2		6	66	76
12.1 - 14.0												21	21
14.1 - 16.0												10	10
16.1 - 18.0													
18.1 - 20.0												3	3
20.1 - 30.0													
30.1 +													
Total	55	52	80	68	73	72	71	62	62	50	51	304	1,000

TABLE 7.26

Ventilation coefficient vs. wind speed in the mixed layer

Maniwaki - Summer

% FREQUENCY OF OCCURRENCE (x 10)

Wind Speed in the Mixed Layer (metres/second)	Ventilation Coefficient $(m^2/sec)/100$												
	0 to 10	11 to 20	21 to 30	31 to 40	41 to 50	51 to 60	61 to 70	71 to 80	81 to 90	91 to 100	101 to 110	111 +	Total
0.0 - 2.0	152	24	8										184
2.1 - 4.0	45	92	63	29	6	1	3						239
4.1 - 6.0	15	24	53	49	27	20	13	1	6	1		1	210
6.1 - 8.0	1	3	14	29	31	20	27	18	12	3	9	6	173
8.1 - 10.0	1		1	6	15	12	16	18	12	6	7	23	117
10.1 - 12.0						1	5	5	3	1	6	23	44
12.1 - 14.0											6	12	18
14.1 - 16.0						1				1	1	11	14
16.1 - 18.0													
18.1 - 20.0												1	1
20.1 - 30.0													
30.1 +													
Total	214	143	139	113	79	55	64	42	33	12	29	77	1,000

TABLE 7.27

Ventilation coefficient vs. wind speed in the mixed layer

Maniwaki - Winter

% FREQUENCY OF OCCURRENCE (x 10)

Wind Speed in the Mixed Layer (metres/second)	Ventilation Coefficient $(m^2/sec)/100$												
	0 to 10	11 to 20	21 to 30	31 to 40	41 to 50	51 to 60	61 to 70	71 to 80	81 to 90	91 to 100	101 to 110	111 +	Total
0.0 - 2.0	16	10	2	1									29
2.1 - 4.0	38	26	28	28	18	16	15	7	1			1	178
4.1 - 6.0	17	24	20	32	29	23	19	19	14	12	10	12	231
6.1 - 8.0	7	16	12	17	18	17	18	14	9	10	9	44	191
8.1 - 10.0	6	2	5	15	7	12	9	7	8	12	6	58	147
10.1 - 12.0	1	3	1	2	5	7	4	6	8	4	9	57	107
12.1 - 14.0		1		2	3	2	2	1	1	6	5	33	56
14.1 - 16.0	1			1		1	1			3	1	26	34
16.1 - 18.0	1						1				1	12	15
18.1 - 20.0												7	7
20.1 - 30.0												5	5
30.1 +													
Total	87	82	68	98	80	78	69	54	41	47	41	255	1,000

TABLE 7.28

Ventilation coefficient vs. wind speed in the mixed layer

Buffalo - Annual

% FREQUENCY OF OCCURRENCE (x 10)

Wind Speed in the Mixed Layer (metres/second)	Ventilation Coefficient $(m^2/sec)/100$												
	0 to 10	11 to 20	21 to 30	31 to 40	41 to 50	51 to 60	61 to 70	71 to 80	81 to 90	91 to 100	101 to 110	111 +	Total
0.0 - 2.0	10	4	4	2									20
2.1 - 4.0	11	10	15	34	34	27	28	13	2			2	176
4.1 - 6.0	13	17	6	25	24	30	31	28	25	23	18	23	263
6.1 - 8.0	2	4	10	8	13	15	18	13	11	11	13	82	200
8.1 - 10.0	6	2	2	8	2	6	4	2	8	10	6	89	145
10.1 - 12.0		2		2	2	2	2	4	8	2	8	70	102
12.1 - 14.0					2		2			2	2	34	42
14.1 - 16.0							2			4		27	33
16.1 - 18.0											2	13	15
18.1 - 20.0												2	2
20.1 - 30.0												2	2
30.1 +													
Total	42	39	37	79	77	80	87	60	54	52	49	344	1,000

TABLE 7.29

Ventilation coefficient vs. wind speed in the mixed layer

Buffalo - Summer

% FREQUENCY OF OCCURRENCE (x 10)

Wind Speed in the Mixed Layer (metres/second)	Ventilation Coefficient $(m^2/sec)/100$												
	0 to 10	11 to 20	21 to 30	31 to 40	41 to 50	51 to 60	61 to 70	71 to 80	81 to 90	91 to 100	101 to 110	111 +	Total
0.0 - 2.0	23	16											39
2.1 - 4.0	66	43	41	21	2	5							178
4.1 - 6.0	23	32	34	39	35	15	6	9	2		2		197
6.1 - 8.0	12	29	14	25	25	20	18	15	6	9	6	3	182
8.1 - 10.0	6	3	9	21	12	20	14	12	7	15	6	25	150
10.1 - 12.0	2	4	3	3	9	14	6	7	7	5	9	41	110
12.1 - 14.0		2		4	5	5	3	3	2	9	9	32	74
14.1 - 16.0	2			2		2				2	3	25	36
16.1 - 18.0	2						2					11	15
18.1 - 20.0												12	12
20.1 - 30.0												7	7
30.1 +													
Total	136	129	101	115	88	81	49	46	24	40	35	156	1,000

TABLE 7.30

Ventilation coefficient vs. wind speed in the mixed layer

Buffalo - Winter

% FREQUENCY OF OCCURRENCE (x 10)

Wind Speed in the Mixed Layer (metres/second)	Ventilation Coefficient (m^2/sec)/100												
	0 to 10	11 to 20	21 to 30	31 to 40	41 to 50	51 to 60	61 to 70	71 to 80	81 to 90	91 to 100	101 to 110	111 +	Total
0.0 - 2.0	10	14	11	6									41
2.1 - 4.0	16	34	31	24	28	9	13	8	3		1	10	177
4.1 - 6.0	15	28	29	25	34	26	27	24	18	9	9	41	285
6.1 - 8.0	4	9	17	19	20	14	15	15	14	9	16	61	213
8.1 - 10.0	4		7	11	15	4	8	13	16	12	11	49	150
10.1 - 12.0		1	1	6	1	4	3	4	6	13	6	32	77
12.1 - 14.0			1	3	4		1	3	1	1	1	24	39
14.1 - 16.0				1		1			1		1	9	13
16.1 - 18.0												4	4
18.1 - 20.0												1	1
20.1 - 30.0													
30.1 +													
Total	49	86	97	95	102	58	67	67	59	44	45	231	1,000

TABLE 7.31

Ventilation coefficient vs. wind speed in the mixed layer

Flint - Annual

% FREQUENCY OF OCCURRENCE (x 10)

Wind Speed in the Mixed Layer (metres/second)	Ventilation Coefficient (m²/sec)/100												
	0 to 10	11 to 20	21 to 30	31 to 40	41 to 50	51 to 60	61 to 70	71 to 80	81 to 90	91 to 100	101 to 110	111 +	Total
0.0 - 2.0	4	13	14	10									41
2.1 - 4.0	10	19	32	25	42	14	23	14	6		2		187
4.1 - 6.0	7	15	18	15	23	33	33	38	31	17	17	19	266
6.1 - 8.0		7	10	8	11	13	13	18	15	14	17	69	195
8.1 - 10.0	3		2	4	8	4	10	8	10	13	10	93	165
10.1 - 12.0		2	2	3		3		6	3	10	4	51	84
12.1 - 14.0			2	2				3				25	32
14.1 - 16.0					1							18	19
16.1 - 18.0												7	7
18.1 - 20.0												2	2
20.1 - 30.0												2	2
30.1 +													
Total	24	56	80	67	84	68	79	87	65	54	50	286	1,000

TABLE 7.32

Ventilation coefficient vs. wind speed in the mixed layer

Flint - Summer

% FREQUENCY OF OCCURRENCE (x 10)

Wind Speed in the Mixed Layer (metres/second)	Ventilation Coefficient (m^2/sec)/100												
	0 to 10	11 to 20	21 to 30	31 to 40	41 to 50	51 to 60	61 to 70	71 to 80	81 to 90	91 to 100	101 to 110	111 +	Total
0.0 - 2.0	16	15	7	3									41
2.1 - 4.0	24	50	31	24	13	3	3	1					149
4.1 - 6.0	24	41	41	35	43	19	21	9	4	1	1		239
6.1 - 8.0	7	12	25	31	30	16	18	12	12	4	15	10	192
8.1 - 10.0	4		13	18	22	4	6	18	22	12	12	28	159
10.1 - 12.0			1	9	1	4	6	2	9	16	9	47	104
12.1 - 14.0				4	7		3	3	3	2		38	60
14.1 - 16.0				2					3		3	31	39
16.1 - 18.0												10	10
18.1 - 20.0												7	7
20.1 - 30.0													
30.1 +													
Total	75	118	118	126	116	46	57	45	53	35	40	171	1,000

TABLE 7.33

Ventilation coefficient vs. wind speed in the mixed layer

Flint - Winter

% FREQUENCY OF OCCURRENCE (x 10)

Wind Speed in the Mixed Layer (metres/second)	Ventilation Coefficient (m^2/sec)/100												Total
	0 to 10	11 to 20	21 to 30	31 to 40	41 to 50	51 to 60	61 to 70	71 to 80	81 to 90	91 to 100	101 to 110	111 +	
0.0 - 2.0	28	5	3			1							37
2.1 - 4.0	45	44	28	20	12	6	9	3		1	1		169
4.1 - 6.0	25	40	35	36	20	21	13	13	12	11	4	8	238
6.1 - 8.0	9	13	23	31	27	28	18	17	11	12	10	33	232
8.1 - 10.0	5	6	9	12	20	12	15	9	9	7	8	42	154
10.1 - 12.0	2		1	6	10	6	7	6	9	7	6	32	92
12.1 - 14.0					1	4	5	1	3	1	4	28	47
14.1 - 16.0					1	1	1			1		12	16
16.1 - 18.0					1				1			7	9
18.1 - 20.0				1			1					1	3
20.1 - 30.0												3	3
30.1 +													
Total	114	108	99	106	92	79	69	49	45	40	33	166	1,000

TABLE 7.34

Ventilation coefficient vs. wind speed in the mixed layer

Sault Ste. Marie - Annual

% FREQUENCY OF OCCURRENCE (x 10)

Wind Speed in the Mixed Layer (metres/second)	Ventilation Coefficient $(m^2/sec)/100$												
	0 to 10	11 to 20	21 to 30	31 to 40	41 to 50	51 to 60	61 to 70	71 to 80	81 to 90	91 to 100	101 to 110	111 +	Total
0.0 - 2.0	11	2	4			2							19
2.1 - 4.0	17	24	21	23	19	11	17	6		2	2		142
4.1 - 6.0	17	28	10	31	25	29	19	19	21	19	6	15	239
6.1 - 8.0	6	7	15	25	23	25	23	23	13	21	17	63	261
8.1 - 10.0	4	2	2	10	14	10	13	10	10	8	14	67	164
10.1 - 12.0	2			2	8	8	8	4	7	4	6	49	98
12.1 - 14.0						2	6		2	2		36	48
14.1 - 16.0					2							11	13
16.1 - 18.0					2							10	12
18.1 - 20.0													
20.1 - 30.0												4	4
30.1 +													
Total	57	63	52	91	93	87	86	62	53	56	45	255	1,000

TABLE 7.35

Ventilation coefficient vs. wind speed in the mixed layer

Sault Ste. Marie - Summer

% FREQUENCY OF OCCURRENCE (x 10)

Wind Speed in the Mixed Layer (metres/second)	Ventilation Coefficient (m^2/sec)/100												
	0 to 10	11 to 20	21 to 30	31 to 40	41 to 50	51 to 60	61 to 70	71 to 80	81 to 90	91 to 100	101 to 110	111 +	Total
0.0 - 2.0	47	7	2										56
2.1 - 4.0	75	66	36	16	4								197
4.1 - 6.0	34	53	62	41	14	12	6	6	3	2	2		235
6.1 - 8.0	12	20	30	36	32	32	14	11	9	2	3		201
8.1 - 10.0	6	9	15	15	25	15	18	9	9	6	2	15	144
10.1 - 12.0	3		3	11	12	5	6	7	12	11	4	14	88
12.1 - 14.0					3	6	5	2	5		4	20	45
14.1 - 16.0					2	2	2			2	2	12	22
16.1 - 18.0												4	4
18.1 - 20.0				2			2					2	6
20.1 - 30.0												2	2
30.1 +													
Total	177	155	148	121	92	72	53	35	38	23	17	69	1,000

TABLE 7.36

Ventilation coefficient vs. wind speed in the mixed layer

Sault Ste. Marie - Winter

Number/
Numéro

5

OWMC

Ontario Waste Management Corporation

FINAL REPORT

PRIMARY ENVIRONMENTAL INFORMATION

PART 5

DATA BASE FOR ENVIRONMENTALLY SENSITIVE AREAS

Gartner Lee Associates Limited
Engineering Geologists, Hydrogeologists, Biologists, Environmental Consultants

Gartner Lee Associates Limited

Consulting Engineering Geologists and Hydrogeologists

Toronto-Buttonville Airport ▪ Markham, Ontario ▪ L3P 3J9 ▪ 416-477-8400
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PRIMARY ENVIRONMENTAL INFORMATION
PART 5
DATA BASE FOR ENVIRONMENTALLY SENSITIVE AREAS

PROJECT NO. 82-1008

SEPTEMBER, 1982

Gartner Lee Associates Limited

Consulting
Engineering
Geologists and
Hydrogeologists

Toronto-Buttonville Airport ■ Markham,Ontario ■ L3P 3J9 ■ 416-477-8400
Telex - 06-986278

September 2, 1982.

Mr. E.H. Schmidt, P.Eng.,
Project Director,
Ontario Waste Management Corporation,
60 Bloor Street West,
Suite 707,
Toronto, Ontario,
M4W 1A1.

Dear Mr. Schmidt:

Re: Final Report - Primary Environmental Information Data Base for Environmentally Sensitive Areas - GLAL 82-1008

We respectfully submit our final report and appended maps for the above-mentioned study.

A copy of most of the environmental information that we were able to obtain is maintained in our information management system for future reference during subsequent phases of study.

We are pleased to have been of service.

Yours very truly,

GARTNER LEE ASSOCIATES LIMITED

Grant Anderson

E.G. Anderson, P.Eng.,
Project Director.

DSO:jcm

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1.0 INTRODUCTION:

1.1 BACKGROUND:

The Ontario Waste Management Corporation (OWMC) has implemented a "Facilities Development Process" to establish facilities for the treatment and disposal of hazardous liquid industrial waste and other hazardous waste in Ontario.

The process involves a number of different phases. The level of detail for each phase will intensify as the program evolves. The first phase of the process involves the collection and analysis of "Primary Factors" of engineering, planning and environmental information that is basic to the evaluation of various systems options.

This report addresses one part of the Primary Environmental Information and is an inventory of both environmentally sensitive and significant areas (ESAs) data sets. The study area has been limited to Ontario south of latitude 46°N (i.e. south of North Bay).

Recent regional studies designed to identify sites possessing features of environmental importance have taken one of two approaches. Most agencies and groups conducting ESA studies have identified and mapped what they have termed environmentally sensitive areas. These sites presumably contain physical features and/or support biological assemblages which are sensitive to changes created by human activities. To qualify for ESA designation the natural features of the site must be unique, uncommon or be of significance otherwise as defined by specific criteria, irrespective of the site's sensitivity.

In a few cases the studies undertaken have been defined specifically as environmentally significant area studies. In these instances the objective has been primarily to identify those tracts which contain significant natural features. 'Significance' is usually defined in terms of uniqueness, representativeness, rarity and environmental functions. The significant areas approach does not require that predictions of expected sensitivity to broad classes of potential impacts be contained in the report, although these predictions may be made if desired.

ESA studies usually concentrate on land-based, natural environment features. It is important to point out also, that features of social concern such as natural aesthetics (e.g. vistas) have been identified in certain ESA reports. Aquatic resources have been addressed to varying degrees in some studies with wetlands receiving attention in most studies and rivers and streams being studied carefully in a few.

1.2 STUDY OBJECTIVES:

The main objectives of this study are as follows:

(1) to research the type of information available in southern Ontario that relates to the environmental significance and sensitivity of land;

(ii) to provide a bibliography of such information;

(iii) to illustrate on base maps the locations of areas of the province that have had environmentally significant and sensitive areas identified;

(iv) to relate -- in broad terms -- the implications of environmentally sensitive areas to the Facilities Development Process.

It is not an objective of this study to analyse or evaluate any of the environmental information, but only to catalogue the existence of such literature for quick and easy reference at subsequent levels of investigation.

1.3 SCOPE:

In keeping with the stated objectives, the primary emphasis of the study concentrated on the cataloguing of both published and unpublished provincial and regional studies previously completed by Conservation Authorities, municipalities, and government ministries.

While we realize that much more detailed information on site-specific environmentally sensitive areas does exist, no attempt is made to catalogue it at this primary phase. Documentation and analysis of these more detailed data will be done at a later phase when there is a better understanding of the facilities development options and possible facility locations are identified.

2.0 METHODOLOGY:

This report documents the findings of a literature review. Specific types of environmental literature pertaining to southern Ontario have been catalogued. This literature refers specifically to environmentally significant and sensitive areas (ESAs).

The first task completed in this review involved contacting a number of individuals across the province who have a local knowledge of environmentally sensitive areas. These included provincial and municipal government officials, naturalists, conservation authority personnel and university professors. The librarians at Gartner Lee Associates Limited also carried out a thorough search of in-house library facilities.

Next, our biologists contacted more than 70 individuals by telephone and obtained exact titles of the reports. When available, the appropriate documents were ordered and placed within an environmental information data base.

In some instances we arranged personal interviews with officials to discuss the type and extent of environmental information that is available for certain geographic areas.

The geographic locations of these studies were then plotted onto base maps to provide a ready visual reference for the rapid location of such information.

A file index of the researched literature has been compiled and the bibliography appended to this report provides references by author. Figures 1, 2, and 3 indicate portions of southern Ontario for which ESA information is available.

The general significance of ESA information as it relates to the Facilities Development Process, is described in the last chapter of this report.

3.0 STUDY RESULTS:

3.1 ORGANIZATION OF DATA:

The information has been organized into three basic categories, each representative of the agencies which sponsored the ESA studies. These three categories are:

(1) Natural areas of provincial significance as identified by the Ministry of Natural Resources (MNR), (Figure 1);

(ii) Conservation Authorities that have completed studies within their basins (Figure 2);

(iii) Studies commissioned within all or part of a municipal government's political boundaries, (Figure 3).

This report contains a bibliography (Section 6) in which each piece of literature is catalogued alphabetically by author, with appropriate references as to year and source of literature. Unpublished ESA information sets are also noted within this bibliography.

3.2 NATURAL AREAS OF PROVINCIAL SIGNIFICANCE AS MAPPED BY MINISTRY OF NATURAL RESOURCES (FIGURE 1)

The Ministry of Natural Resources has divided the province of Ontario into Site Regions and Site Districts. The regions and districts for southern Ontario are shown on Figure 1. The boundaries of the site regions are based on broad vegetation zones, while the site districts are based on physiographic zones (Lindsay 1981: p.4). There are three site regions and 26 site districts south of the 46° parallel.

After dividing the province into the various site regions and site districts, staff of the MNR (Parks and Recreation Section) have carried out provincial studies within a number of these site districts and have mapped information at a scale of 1:250,000.

"The purpose of these studies is to identify areas which best illustrate unique and representative biological and physical features. The sites selected are intended either for acquisition to form a system of Natural Reserve parks, or for protection through a variety of other means, such as the use of private and public land agreements" (Ontario Ministry of Natural Resources, Central Region 1982).

Figure 1 also shows those sections of southern Ontario where studies have already identified natural areas of provincial significance. These sections are the Southwestern, Central and Eastern Regions of MNR.

The information provided in these site district studies is provincial in scope but it also identifies some site-specific conditions. As such, the information is both important and significant to any facilities options contemplated by the Ontario Waste Management Corporation.

When it is required, additional, more detailed information can be obtained by contacting appropriate staff in the Parks and Recreation Section (Central Region, in particular) of MNR.

3.3 ENVIRONMENTALLY SENSITIVE AREAS BY CONSERVATION AUTHORITES (FIGURE 2):

Figure 2 shows the location of Conservation Authority jurisdictions in Southern Ontario. While virtually all of these Authorities have delineated environmentally sensitive areas within their basins, only the ones shaded on Figure 2 apparently have reports available covering all or part of their watersheds. ESA reports are available for 19 of 35 conservation authority watersheds south of the 46° parallel. In addition, there exists unpublished information files in Conservation Authority offices, much of which is referenced in the bibliography.

In some instances site-specific information is maintained on file within the Authority and Resource Managers can provide guidance and further detail within their jurisdictions.

Generally, each watershed covers a number of municipalities in part, or entirely. ESA sites are usually mapped at a scale of 1:50,000 in finalized reports.

As opposed to work done by MNR, the scope here is at the drainage basin level and the purpose of these studies is to identify areas having important natural features. This aids in planning for wildlife, soil and water conservation practices and provides input to municipal official plans.

3.4 MUNICIPALITIES WITH ENVIRONMENTALLY SENSITIVE AREAS INFORMATION (FIGURE 3):

Figure 3 shows those municipalities within southern Ontario that have prepared formal environmentally sensitive areas reports. Eagles (1981) identifies a number of additional municipalities which utilize studies carried out by conservation authorities. Information is in print for 14 municipalities south of the 46° parallel.

The purpose of these studies is to identify significant and sensitive areas and incorporate this information into regional plans and official plans for municipalities.

'Municipalities' refers to either individual counties or individual regional municipalities. They usually cover a smaller area than a watershed and the location of ESA sites is mapped, in many instances, at a scale of 1:50,000 or 1:25,000. Thus, this information is local in nature and is therefore more detailed than the work done by MNR Regions.

Local environmental information is often available and can be obtained by contacting staff in planning and environmental departments of administrative or municipal offices.

3.5 OTHER SOURCES OF INFORMATION:

Ontario Hydro (Hounsell 1982), has done extensive cataloguing of environmental conditions in southern Ontario, and while these references are not spatially portrayed on a map, they are included in the bibliography. This more detailed information should be researched at a later phase in the Facilities Development Process when the facilities options and possible locations are better defined.

The Ontario Ministry of Natural Resources has assembled ESA mapping at certain district offices. As part of the background information assembly process for district land use strategy plans, MNR has organized certain types of available ESA information. MNR also co-operated with the University of Toronto to produce an unpublished list of International Biological Program (IBP) sites in Ontario. Many IBP sites provide habitat for uncommon plant and animal species.

4.0 EVALUATION OF DATA BASE:

4.1 DISCUSSION OF EXISTING DATA BASE:

The data base collected to date includes over 50 reports or unpublished information sets. Style and format of ESA reports vary. Two approaches that are common are described in papers by Eagles (1981), and Osmond and McQuay (1981). Briefly, Eagles defined an ESA as "A specifically bounded landscape that fulfills one or more of a set of criteria." Areas are identified as "sensitive" or not. Osmond and McQuay, on the other hand, have approached identification of ESAs by assigning significance to areas. Both approaches use specific physical and biological details but Eagles would fit areas directly into a sensitive category, while Osmond and McQuay go through another step. Osmond and McQuay assign significance based on "environmental *functions* served by the physical and or biological component" and "unusual *attributes* possessed by the physical or biological component." The vulnerability to disturbance or sensitivity of significant areas was determined and rated.

Most of the studies have a certain degree of subjective treatment of data. This is illustrated in the Brant County study (Eagles 1980: p.39), statement "Although some of these areas may have fulfilled one or more of the criteria, they were excluded from the environmentally sensitive category due to rather marginal fulfillment of the criteria."

The nature of the study may vary. For example, the study done by Hough, Stansbury and Michalski Limited (1982), was an "amenity" study. It contains useful information on fish and wildlife habitats and forest resources (not ESAs) and the study was related more to "the natural and man-made resources which provide opportunities for public outdoor recreation, scenic enjoyment and an increased understanding of the Basin's history, resources, and conservation management programs."

The scope of each study must be considered as well. In some studies, data were gathered for one or two years. In others, the data base may have had a ten year collection period. Studies covering a larger area such as MNR regions on a provincial basis will have a tendency to exclude areas that a more local study would include. A watershed or county study may contain as many as 80 ESAs while the MNR study may contain as few as 20 areas over the same geographic area.

Some data are in an unfinished form. This is indicated, to some extent in the bibliography by terms such as "unpublished", "personal communication", "preliminary" and "draft". Any of these data could be subject to change and this should be considered when using this information for analysis.

In some cases, information was out of print such as the report on the Regional Municipality of Niagara (Brady 1982). Other information was too vast to order such as computer information at Ontario Hydro, Toronto (Hounsell

1982). In these cases, the sources were recorded for future examination purposes but copies of the information are not contained in the environmental information data base of the present study.

There is duplication of information among certain reports. This is due to upgrading data and using existing reports as a basis for newer ones.

The present study has dealt mainly with information that is readily available in a report format. In certain areas information can only be obtained through contact with local naturalist clubs, MNR district offices, other organizations and private individuals.

One major area lacking general ESA information is the area lying south of the 46° parallel extending from Georgian Bay eastwards to the Ottawa River through central Ontario (Figure 2). In addition to this large tract of land, there are a number of drainage basins elsewhere lacking published information.

4.2 SIGNIFICANCE OF DATA BASE TO FACILITIES DEVELOPMENT PROCESS:

As the Facilities Development Process program develops, the evaluation of specific environmentally sensitive areas may intensify and become very site-specific. At the present time, however, the cataloguing of such environmental information is important in at least three ways.

First, it provides an effective base for future studies. In dealing with environmentally sensitive areas (ESA), it is often the degree of development or land use alteration allowed, that is of importance (Eagles, 1981). Thus, the existence of an ESA does not disqualify it as a possible facility site, but warns the proponent that careful future investigations are necessary to determine the extent of any potential environmental interference.

Second, the catalogue provides a good source of information that allows us to identify and "red flag" potentially sensitive and significant areas very early in the development process. By referring to the reports in the bibliography we can determine whether any future conflicts with ESAs are likely to occur.

The third point is that we can quickly identify areas of major environmental concern and readily document the sources of such concern. Thus, at an early stage we are cognizant of major environmentally sensitive areas within the province.

5.0 SUMMARY AND CONCLUSIONS:

All major environmentally sensitive and significant areas mapping projects carried out in southern Ontario have been catalogued in a bibliography which contains the titles of over 50 such reports and maps. Both published and unpublished data sets are cited.

Three figures show the geographic areas where such studies have been completed in southern Ontario. Figure 1 shows natural areas of provincial significance. Figure 2 shows conservation authorities with completed studies and Figure 3 shows municipalities that have published studies.

This data base is now ready to be utilized in the Facilities Development Process. It can be used to quickly delineate major, known areas of environmental significance and/or sensitivity. This type of information is essential to developing environmentally compatible plans for specific sites.

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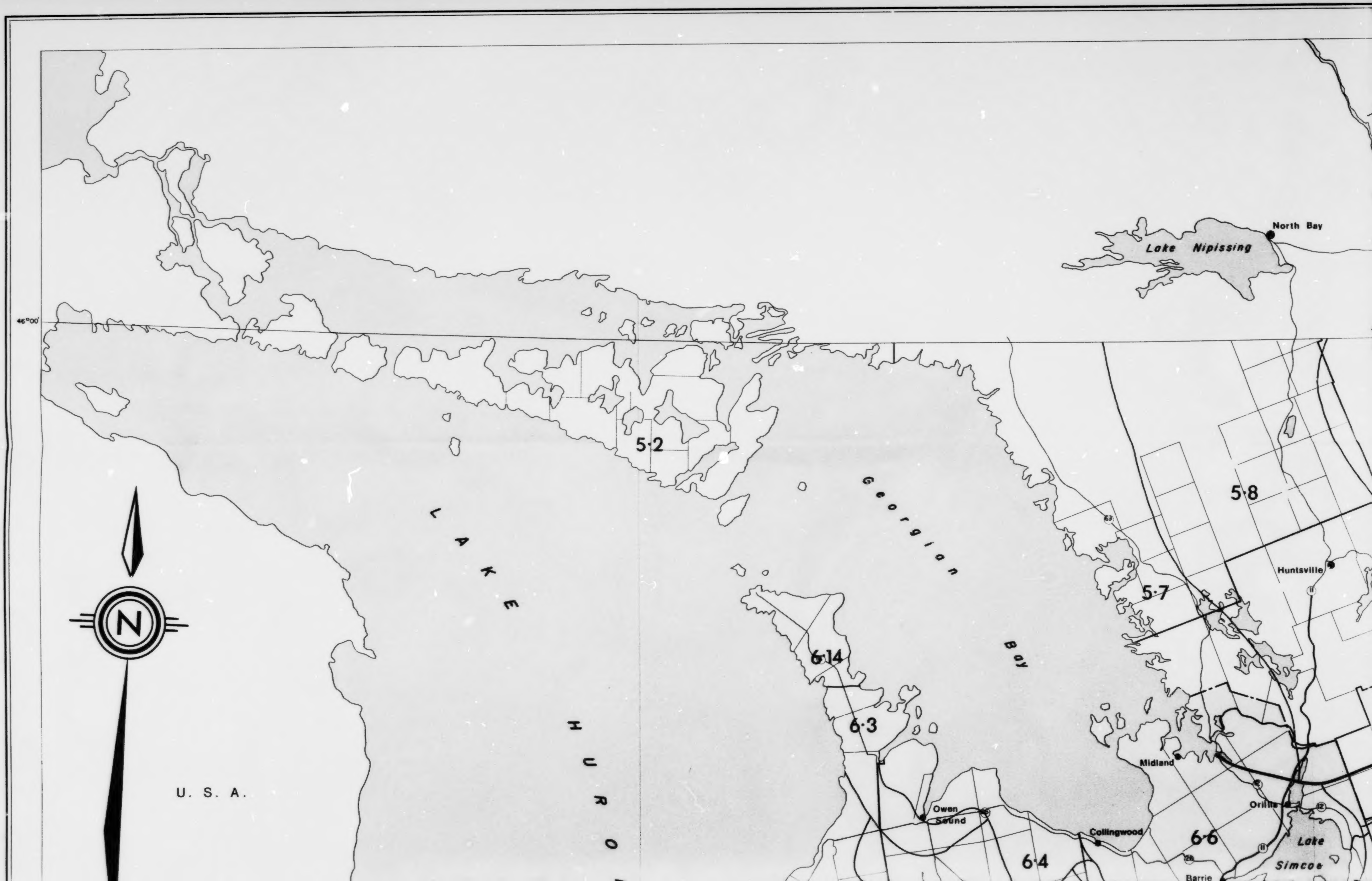
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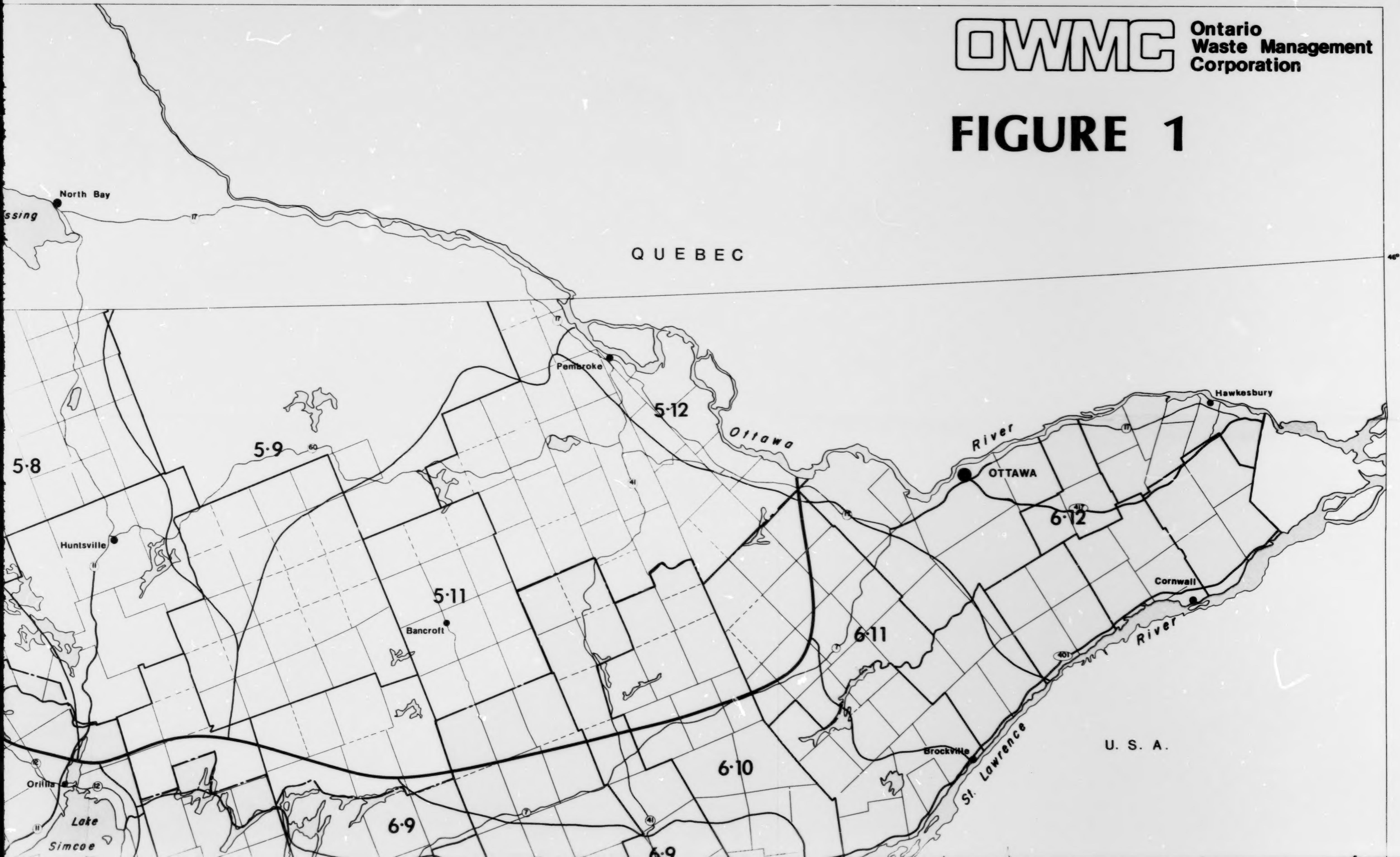
FIGURE 1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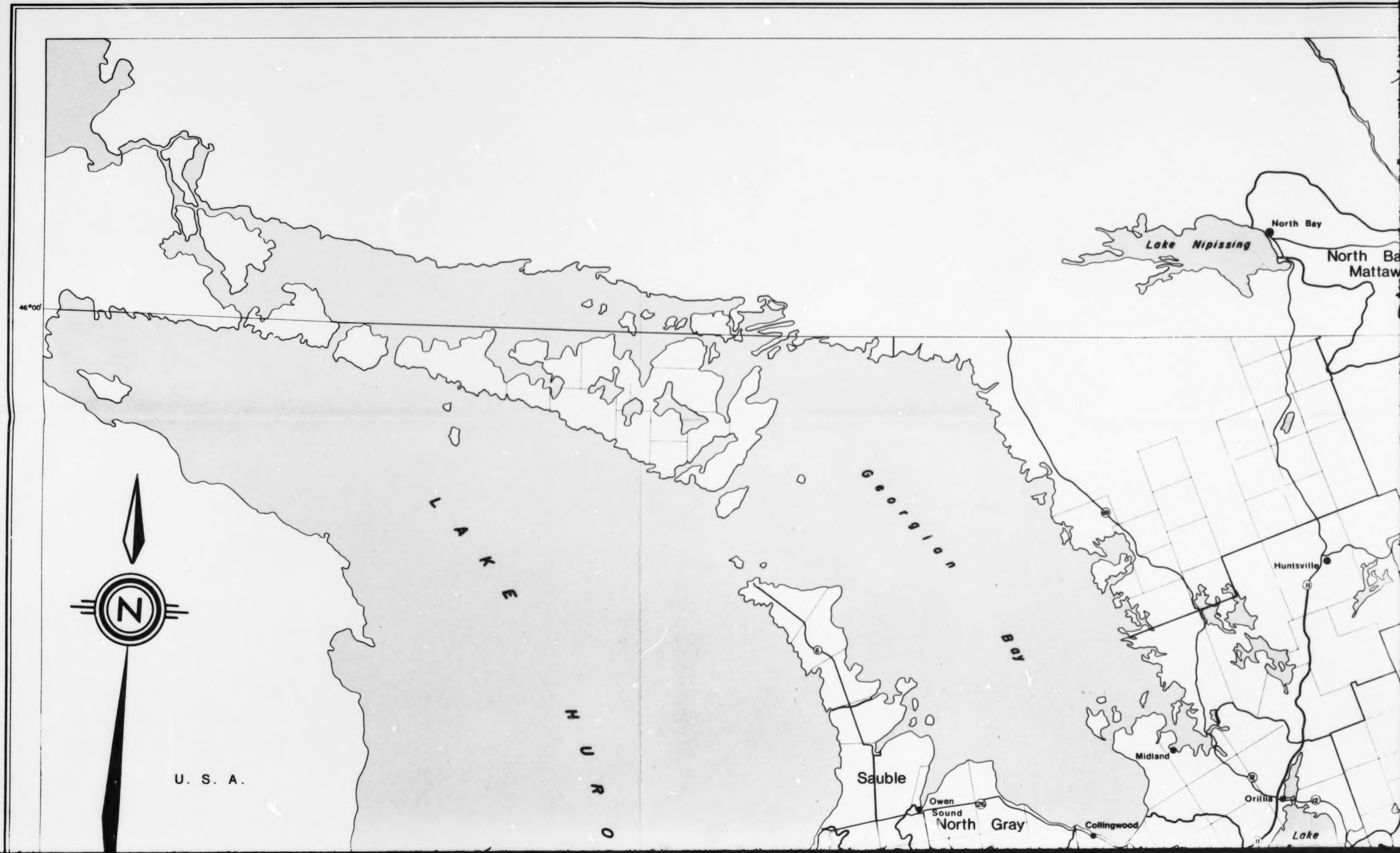
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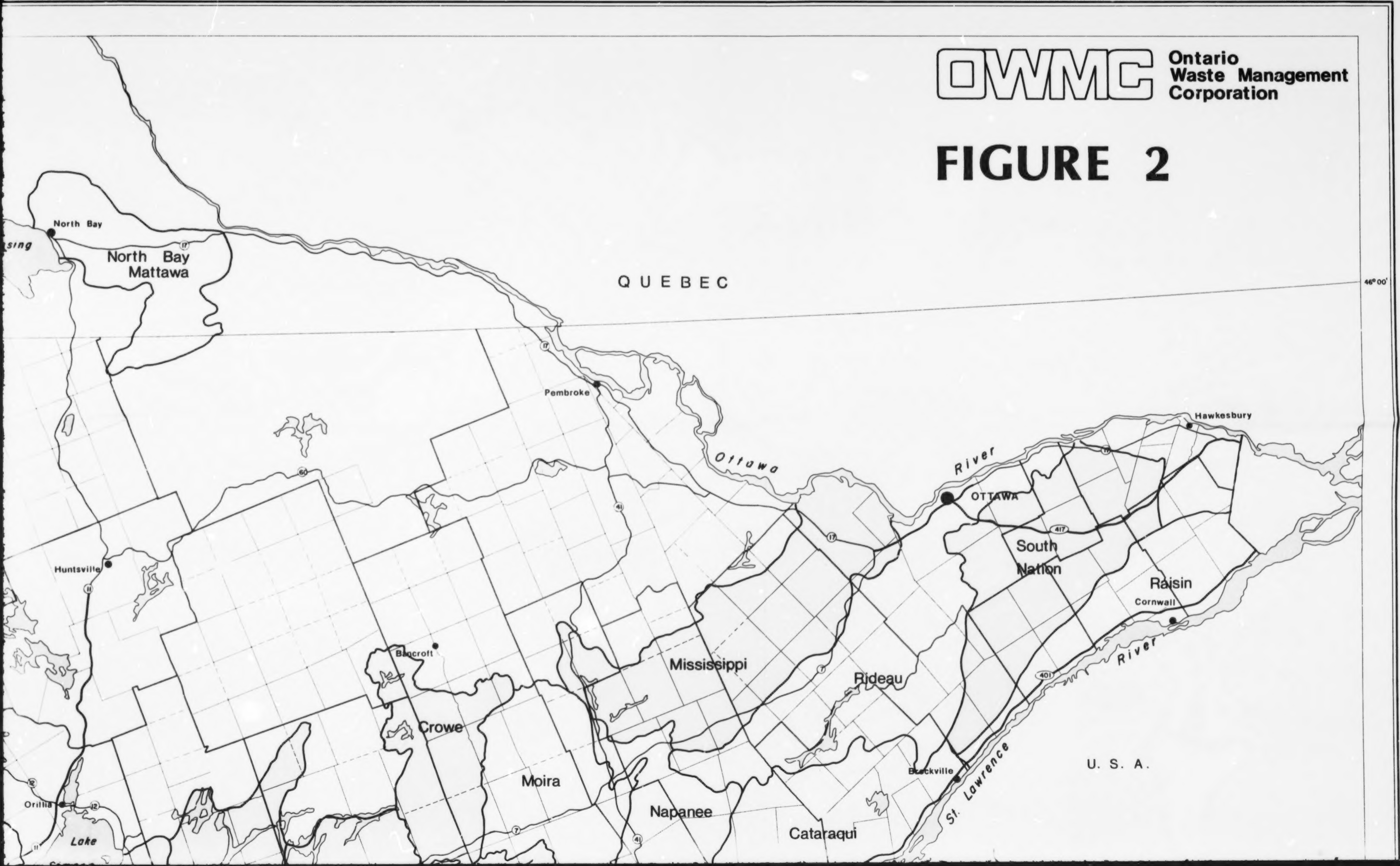
FIGURE 2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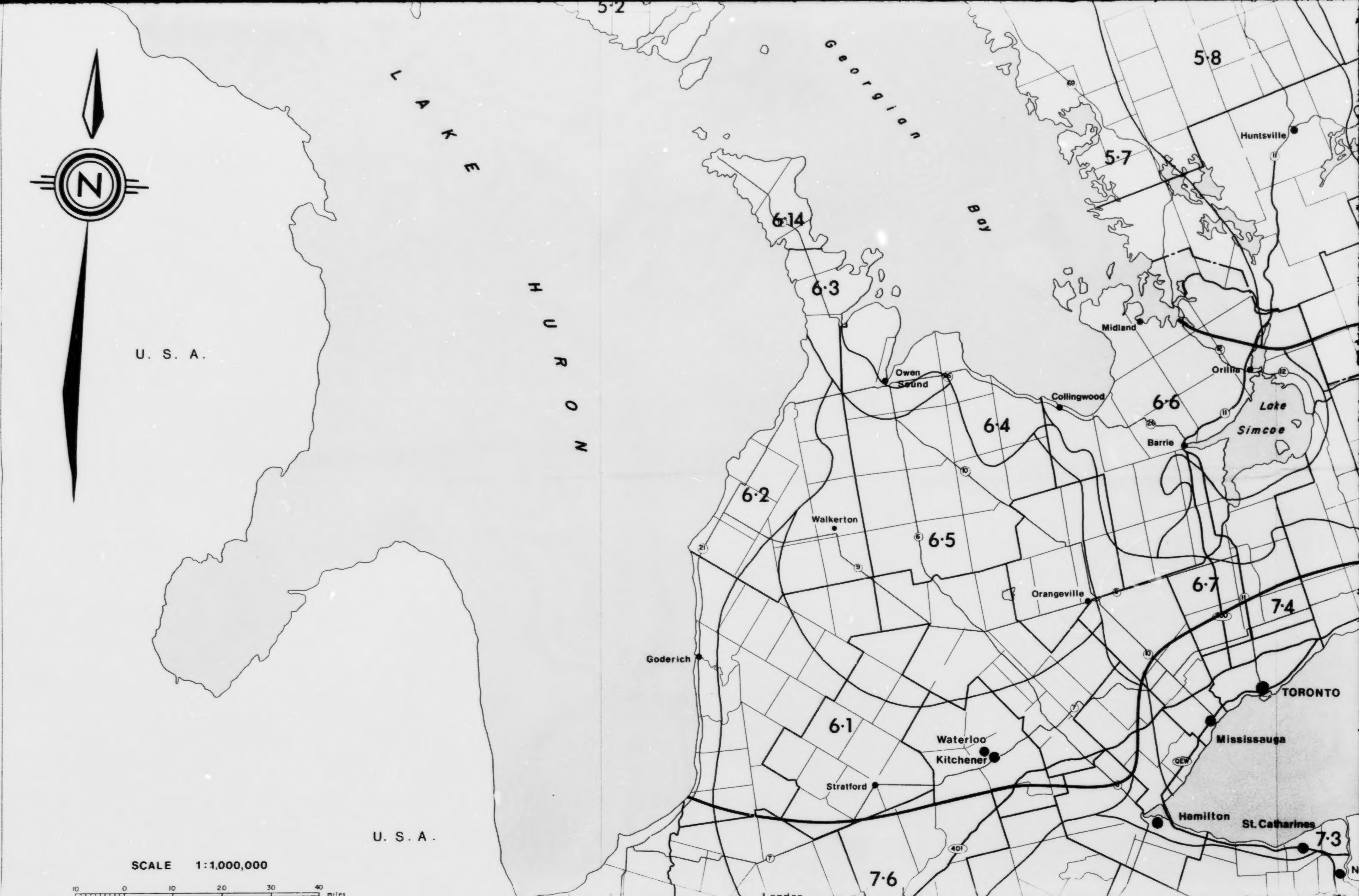
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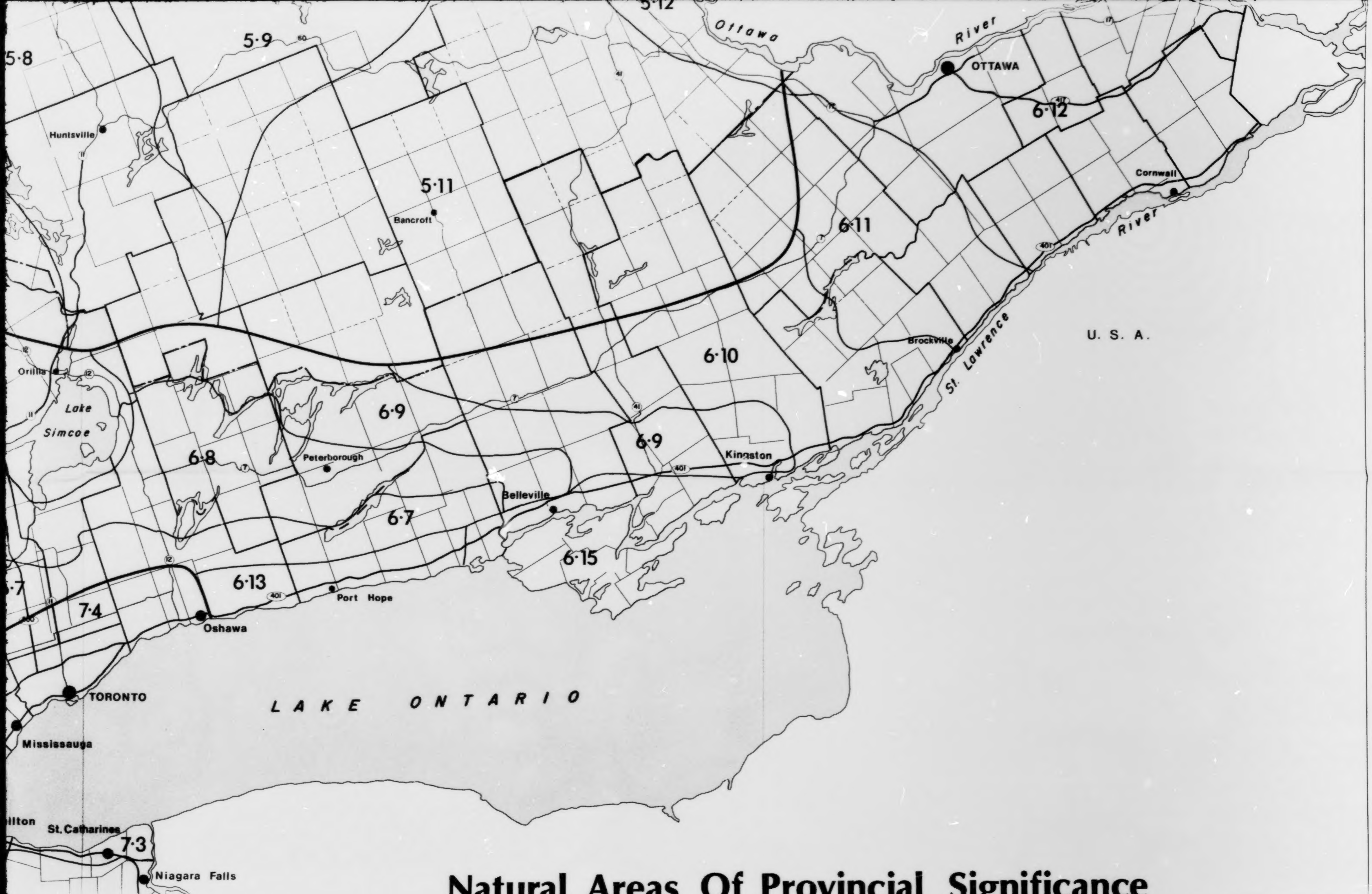
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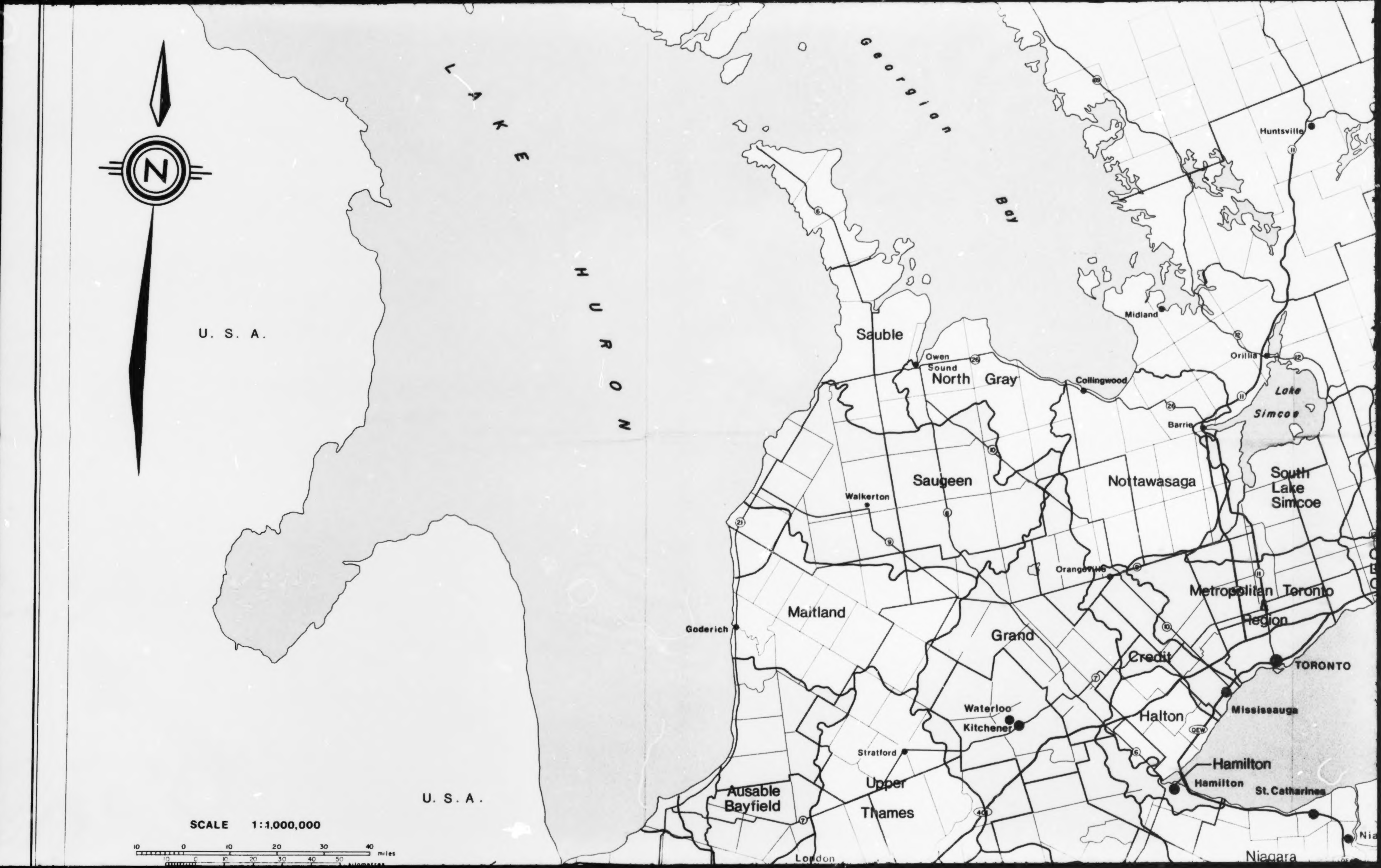
Natural Areas Of Provincial Significance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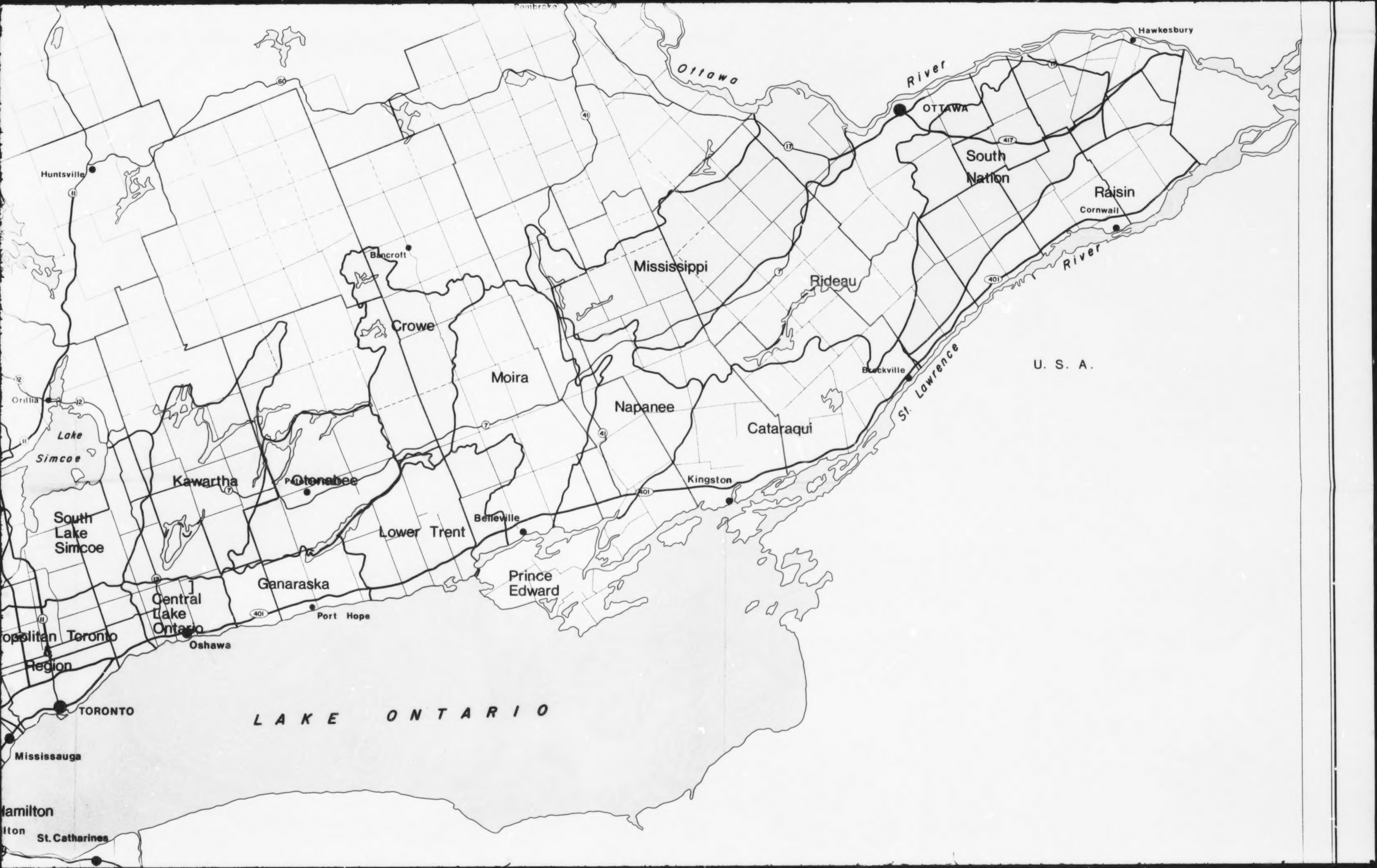
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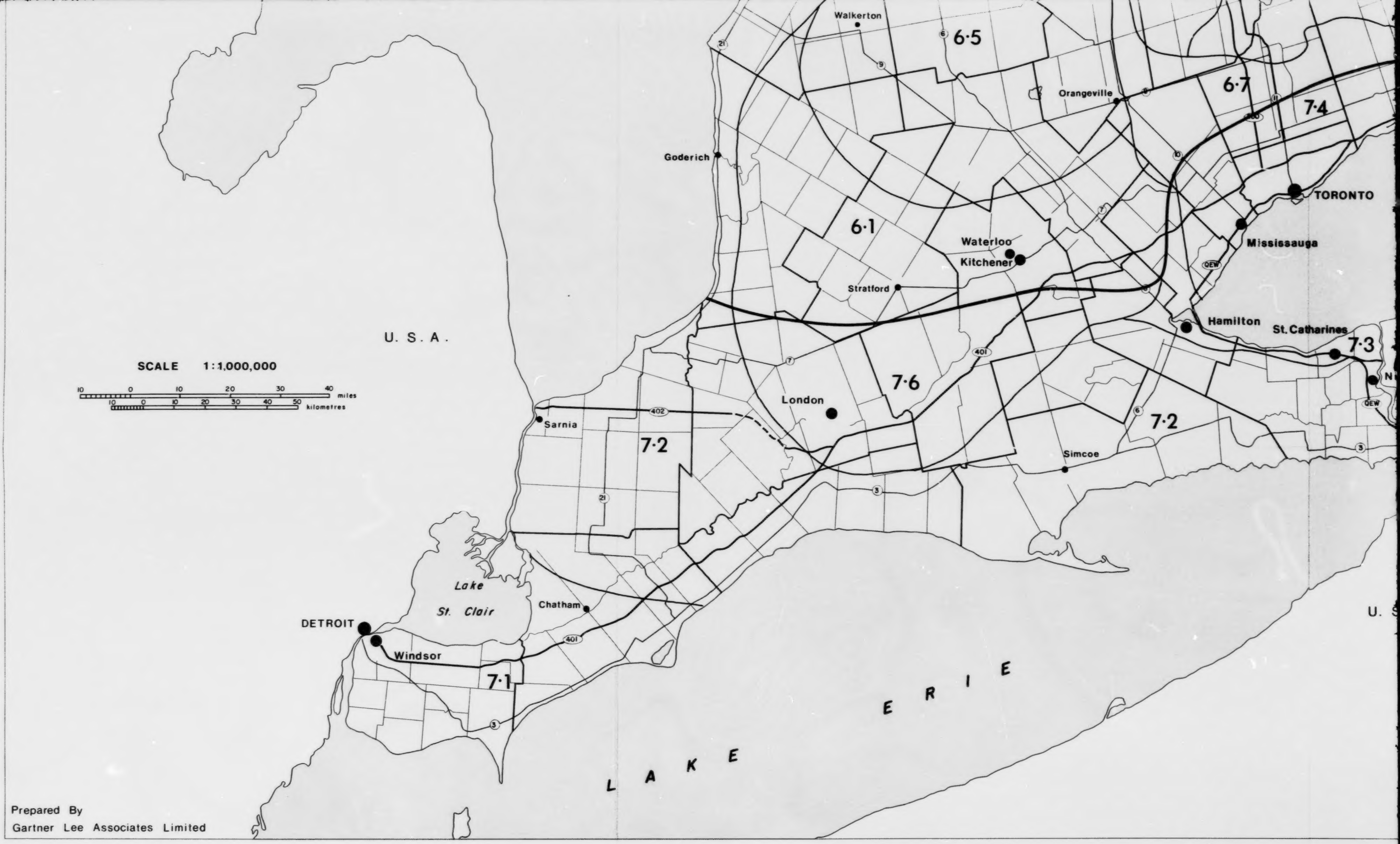
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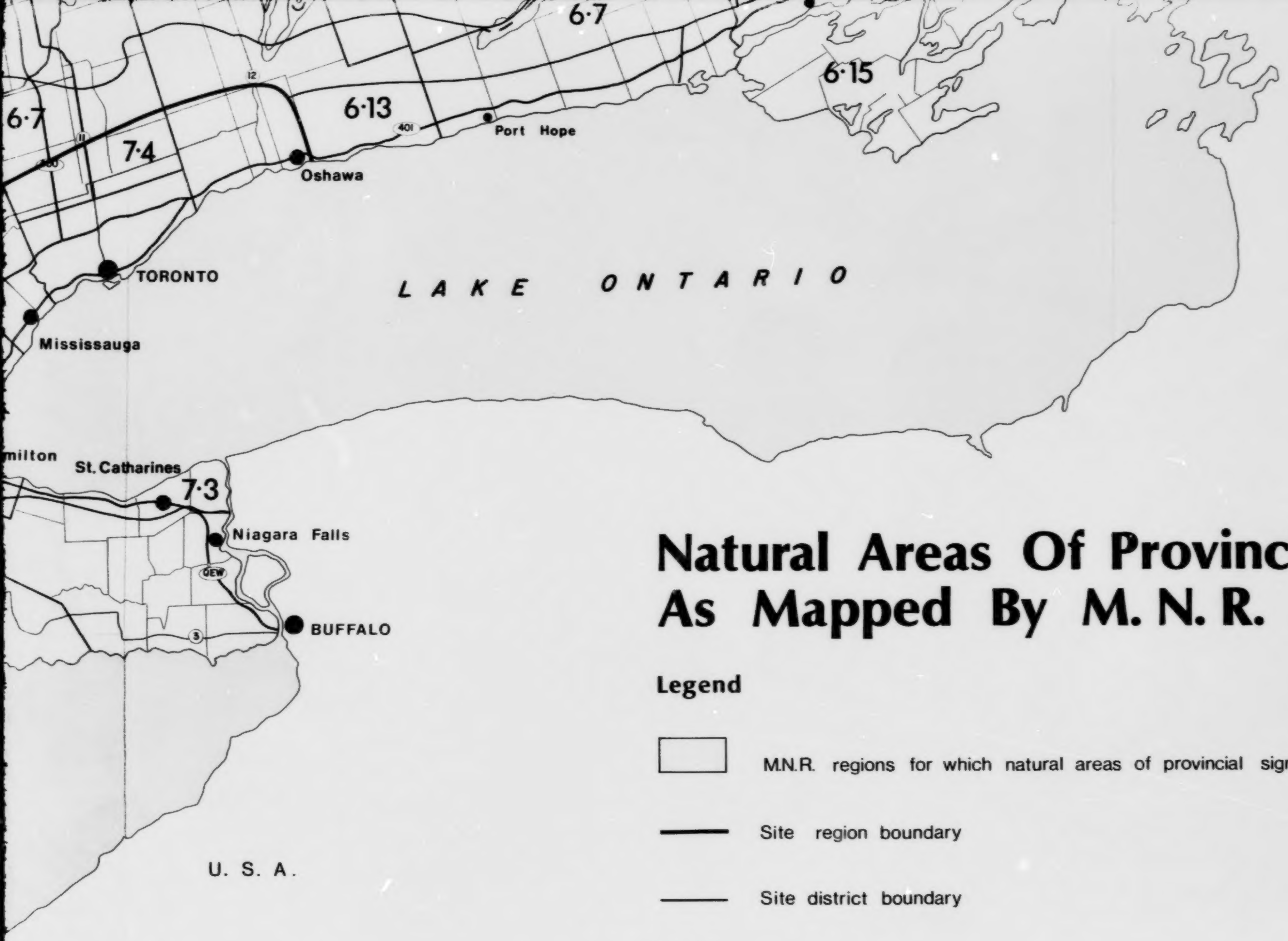
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Natural Areas Of Provincial Significance As Mapped By M. N. R.

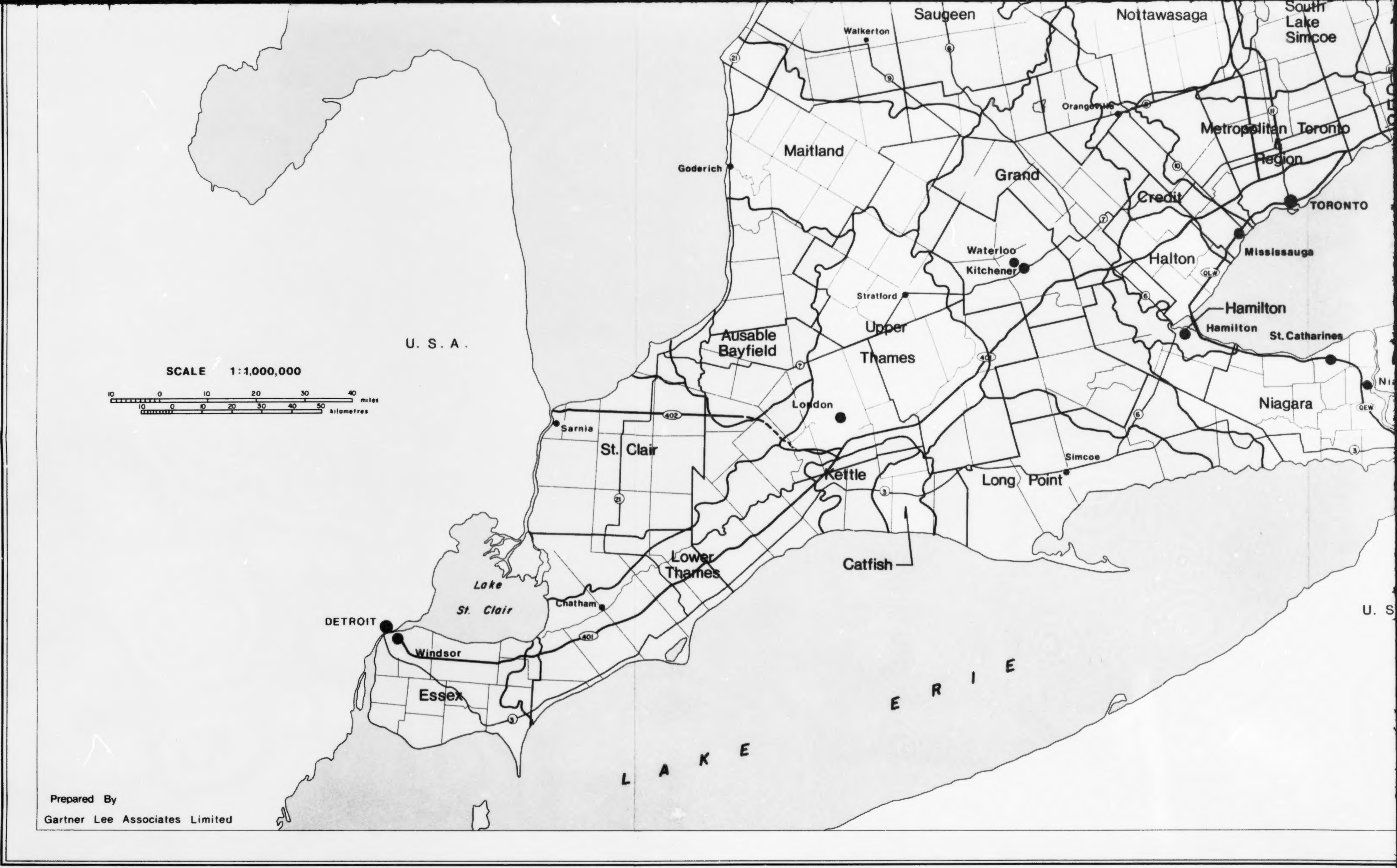
Legend

☐ M.N.R. regions for which natural areas of provincial significance have been identified

━ Site region boundary

— Site district boundary

7·2 Site district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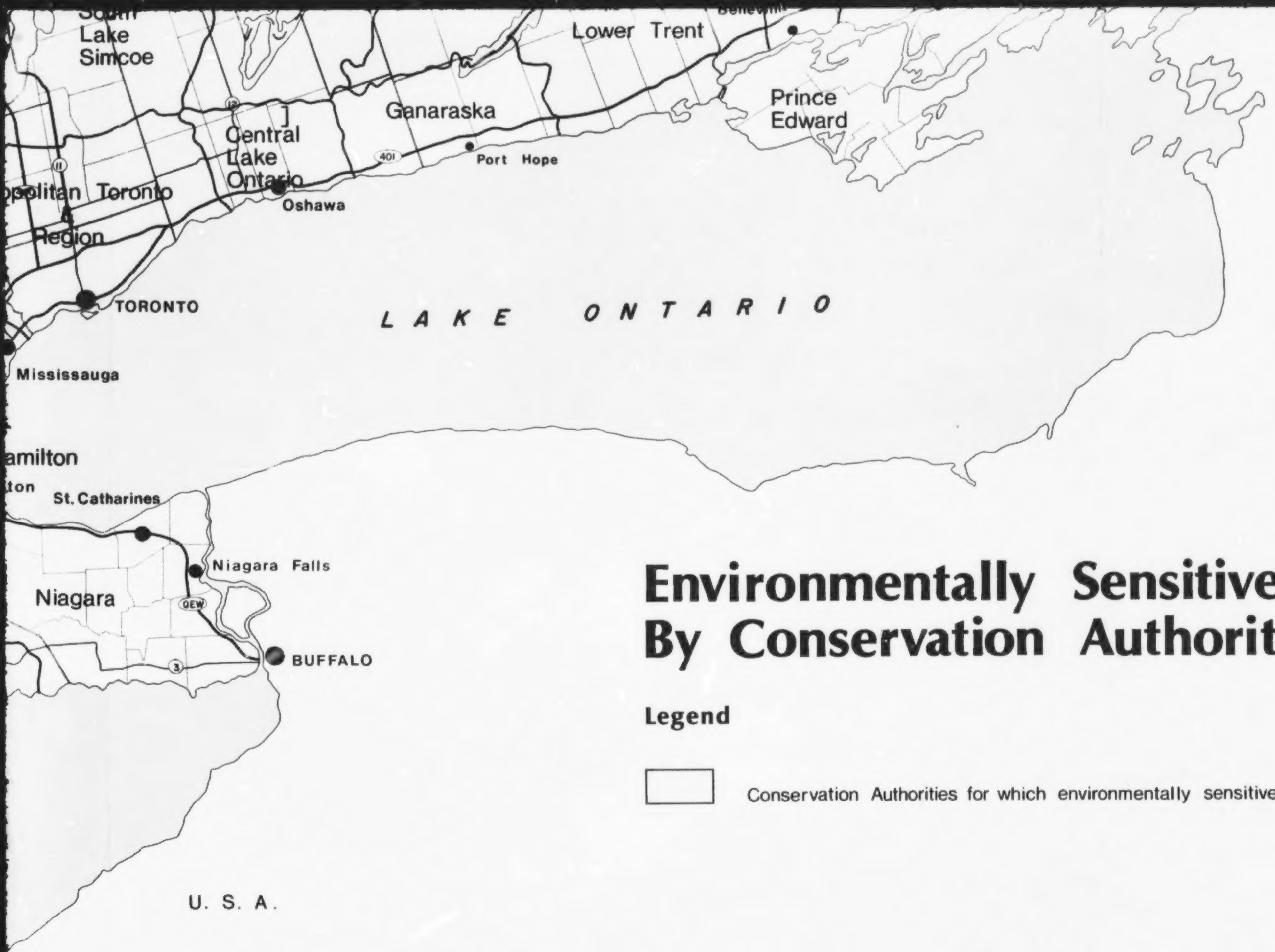
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Environmentally Sensitive Areas Information By Conservation Authorities

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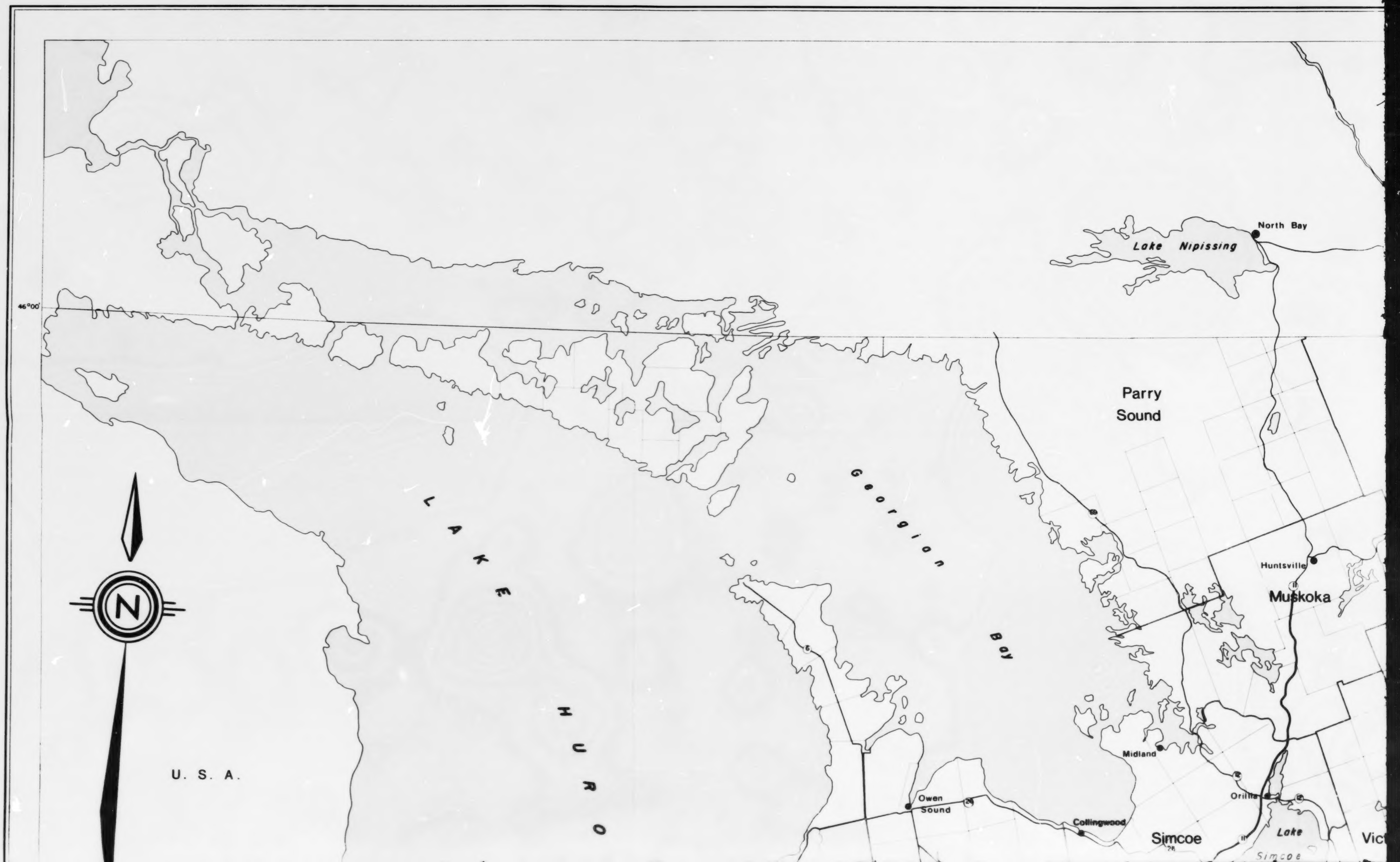
☐ Conservation Authorities for which environmentally sensitive areas reports available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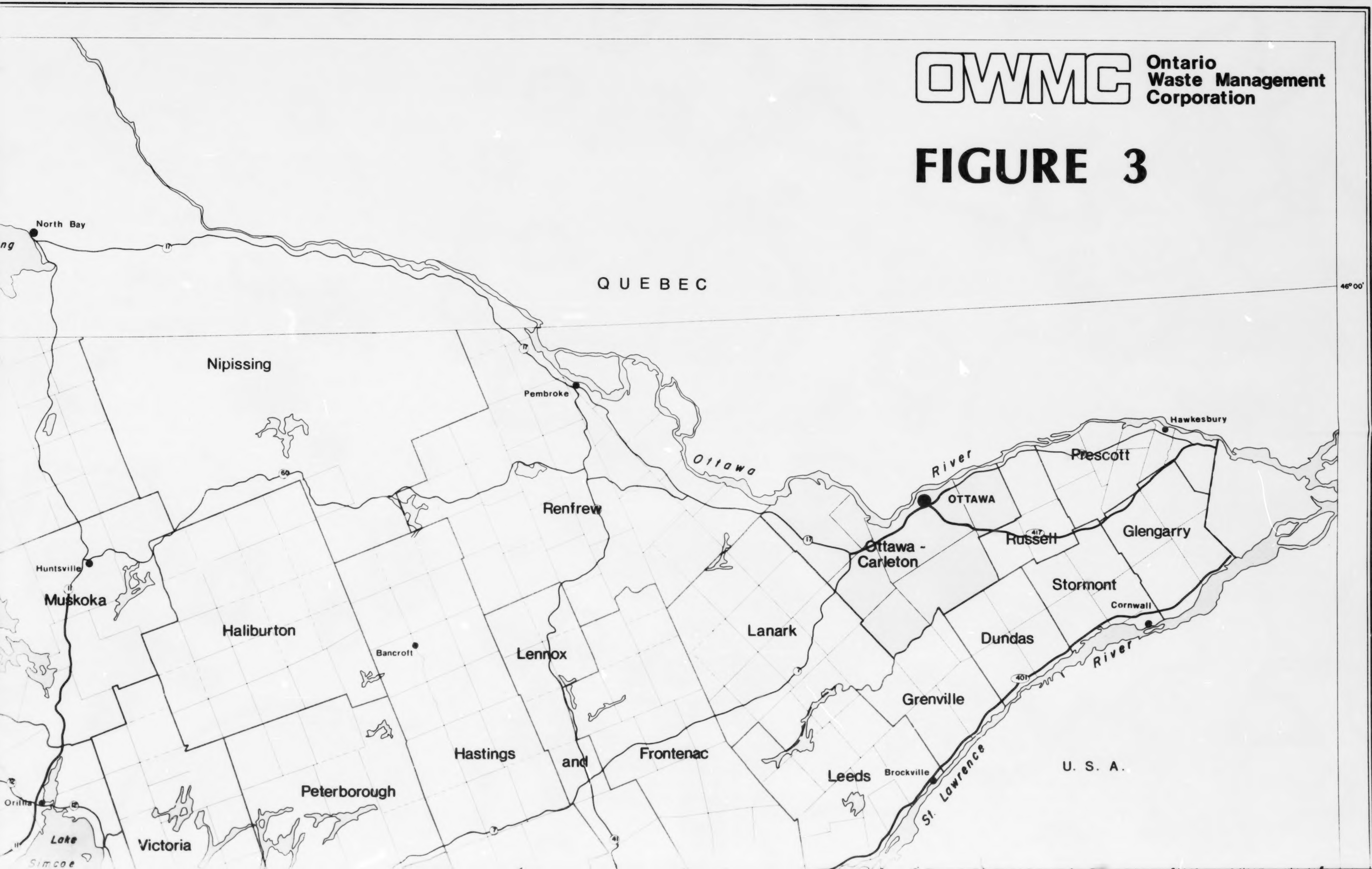
Ontario Waste Management Corporation

FIGURE 3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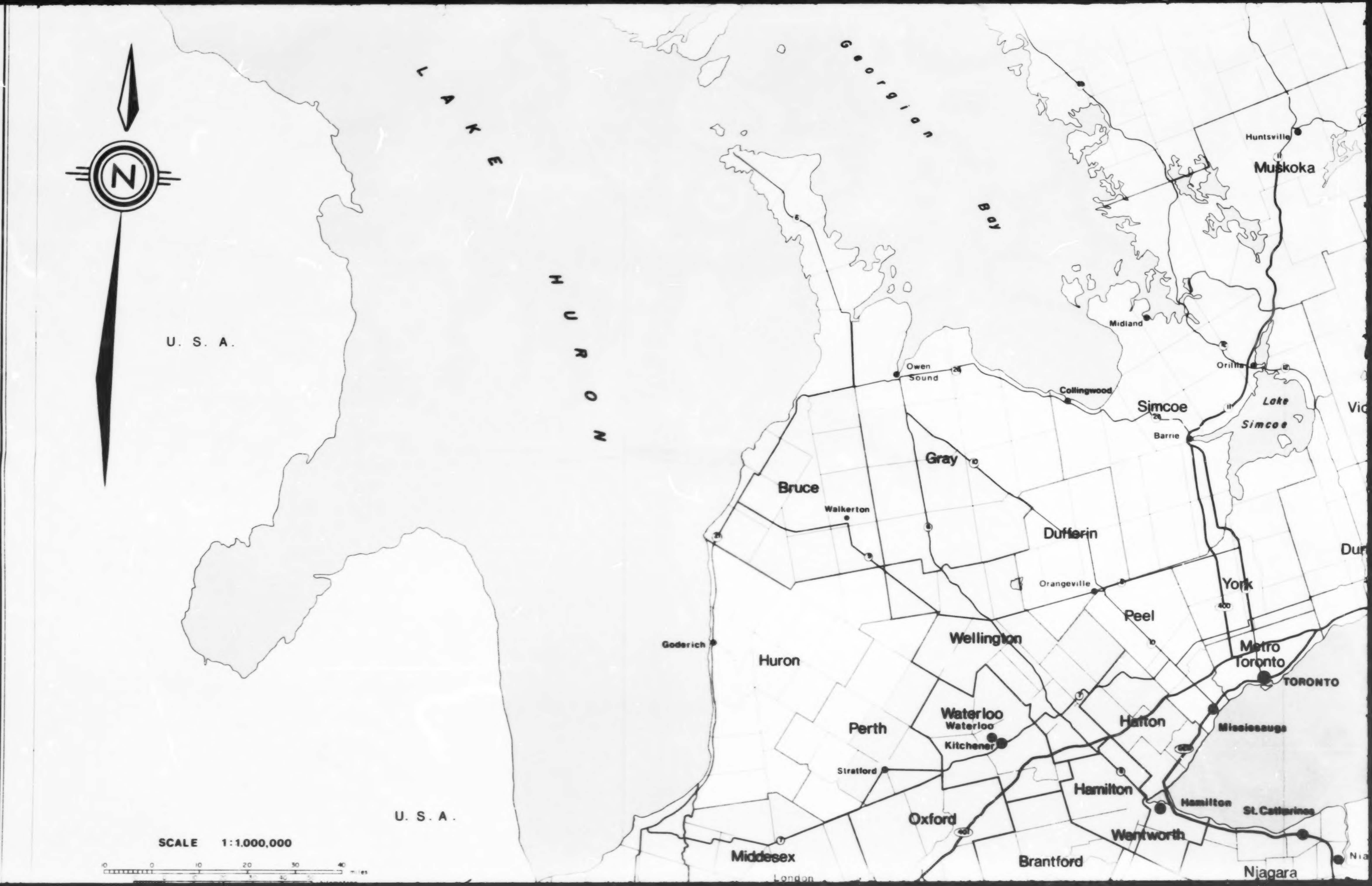

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Huntsville
Muskoka
Midland
Orillia
Lake Simcoe
Simcoe
Barrie
Collingwood
Owen Sound
Gray
Bruce
Walkerton
Dufferin
Orangeville
York
Peel
Wellington
Goderich
Huron
Metro Toronto
TORONTO
Mississauga
Halton
Waterloo
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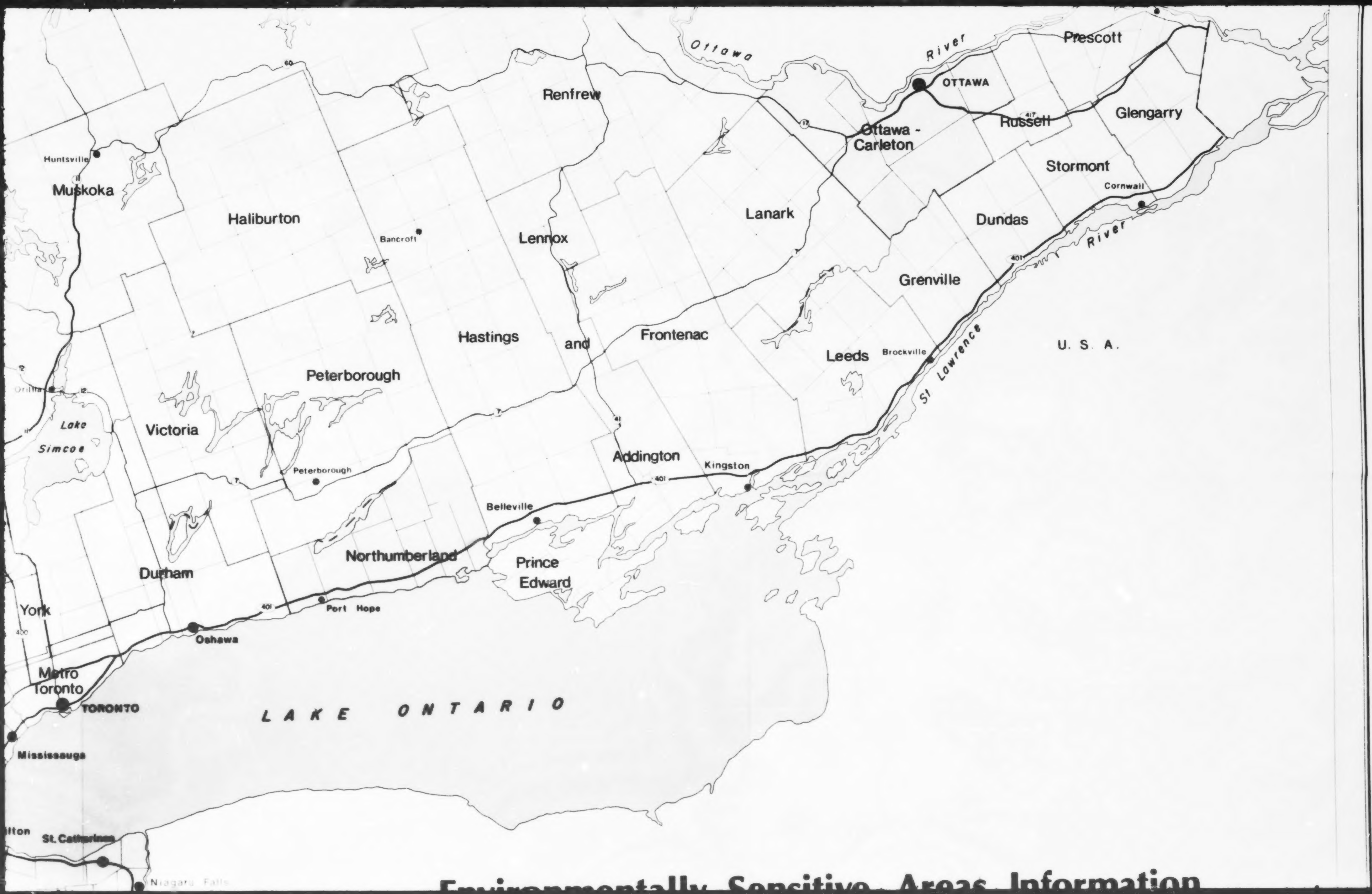
Simcoe
Ottawa River
Prescott
OTTAWA
Renfrew
Ottawa - Carleton
Russell
Glengarry
417
17
60
Huntsville
Muskoka
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Haliburton
Bancroft
Lennox
Lanark
Stormont
Cornwall
Dundas
River
401
Grenville
Hastings
and
Frontenac
Leeds
Brockville
St Lawrence
U. S. A.
Peterborough
12
Orillia
Lake Simcoe
Victoria
7
41
Addington
Kingston
Peterborough
Belleville
Northumberland
Prince Edward
Durham
York
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Port Hope
Oshawa
Metro Toronto
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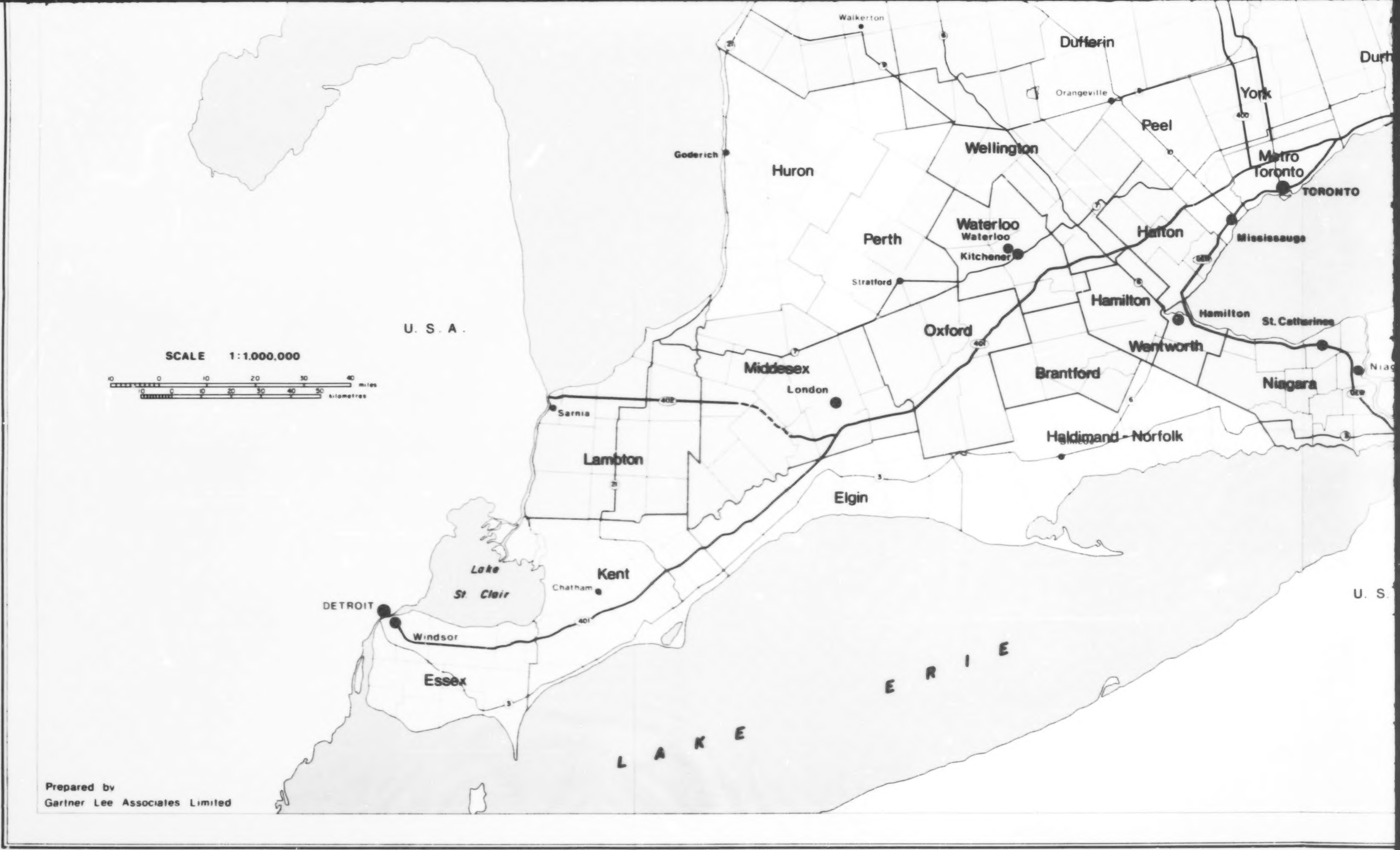
St. Catharines
Niagara Falls

Environmentally Sensitive Areas Information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Elgin
Lake
St. Clair
Kent
Chatham
DETROIT
401
Windsor
Essex
U. S.
LAKE ERIE

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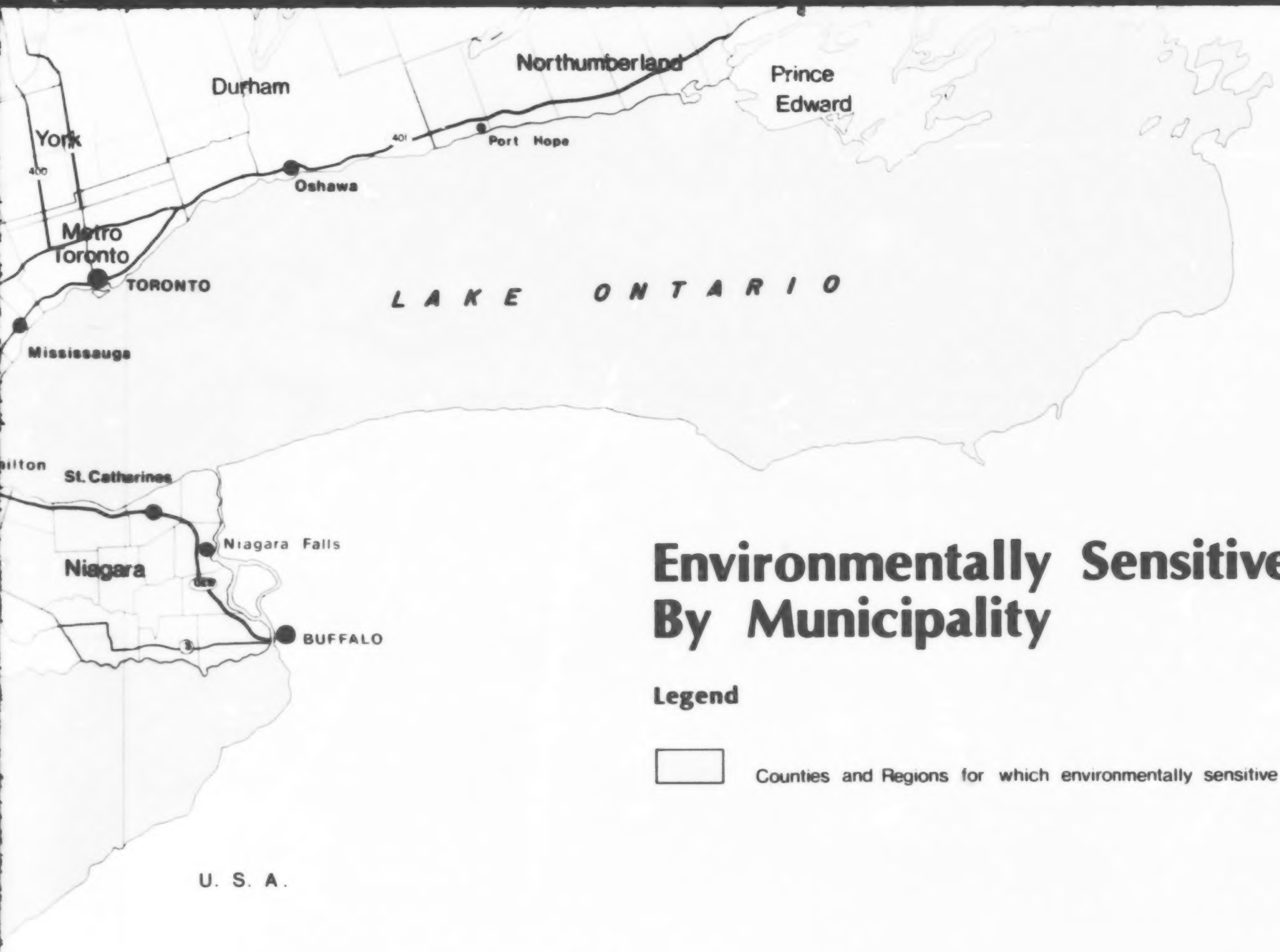
Gartner Lee Associates Limited


Northumberland
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York
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Metro
Toronto
TORONTO
LAKE ONTARIO
Mississauga
ilton
St. Catharines
Niagara Falls
Niagara
BUFFALO
U. S. A.

Environmentally Sensitive Areas Information By Municipality

Legend

☐ Counties and Regions for which environmentally sensitive areas information is available